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MODELING AND ANALYSIS OF SELECTED SO2 POINT SOURCES IN WISCONSIN. PART I

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Geomet, Incorporated

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A study of selected sulfur dioxide sources in Wisconsin was conducted at the request of the Enforcement Division of EPA Region V. The work done consisted of making a selection of the SO_2 sources to be studied, collecting and verifying the emissions data, processing the meteorological data, using computer models to compute the ground-level concentrations of SO_2, and finally analyzing the computer model output.

The 55 plants initially selected for study were based on the quantity of the annual average SO_2 emission. Preliminary modeling provided the basis for making the decision as to whether to do detailed modeling for each plant; detailed modeling, which provided the computed SO_2 concentrations at many locations in the vicinity of each plant, was done for 34 sources, mostly power plants and paper mills.

The results of the model computations indicate that air quality standards are expected to be exceeded on numerous occasions due to SO_2 emissions from 7 of the 34 modeled cases. In 10 other cases, either ambient concentrations may exceed the standards on less frequent occasions, or the modeling technique does not provide a reliable basis for judgement. For the remaining plants, the resulting SO_2 concentrations would be expected to remain well below the applicable standards.

Other aspects of the study include: a limited model validation analysis which gave satisfactory results; preliminary study of the interactive effects of plumes from contiguous plants; and recommendations for further study of the uncertain cases mentioned above, and for cases of multiple contiguous plants.

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PART I

FINAL REPORT

for

Enforcement Division, EPA Region V
230 South Dearborn Street
Chicago, Illinois 60604

EPA Project Officer: Robert Mattis

under

Contract Number 68-02-1442
(Task 1)

by

Scott D. Thayer
Douglas J. Pelton

GEOMET

MODELING AND ANALYSIS OF SELECTED SO_2 POINT SOURCES IN WISCONSIN

PART I

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GEOMET, Incorporated
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Task Number 1

EPA Project Officer: Robert Mattis

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ENVIRONMENTAL PROTECTION AGENCY
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February 1975

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This report has been reviewed by the Enforcement Division, EPA Region V, Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency.

The complete report is in three parts, each bound separately. Part I contains the complete text, and stands alone. Parts II and III contain some six hundred pages of computer printout of the detailed results of each plant modeled; due to their bulk and the fact that they are of interest to a small audience, they have been given only a limited distribution.

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SUMMARY

A study of selected sulfur dioxide sources in Wisconsin has been conducted at the request of the Enforcement Division of EPA Region V. The work done has consisted of making a selection of the SO_2 sources to be studied, collecting and verifying the emissions data, processing the meteorological data, using computer models to compute the ground-level concentrations of SO_2 and finally analyzing the computer model output.

The initial step was to select the SO_2 sources which are the most likely to cause problems. An initial list of 27 plants suggested by the Project Officer was expanded by further study to include 55 plants. The 55 plants were selected based on the quantity of the annual average SO_2 emission.

Preliminary modeling of 51 of those plants provided the basis for making the decision as to whether to do detailed modeling for each plant. The preliminary modeling provided a rough estimate of the concentrations which would result from the plant's emissions.

Detailed modeling, which provided the computed SO_2 concentrations at many locations in the vicinity of each plant, was done for 34 plants.

The results of the model computations indicate that air quality standards are expected to be exceeded on numerous occasions due to SO_2 emissions from seven of the 34 modeled cases. In 10 other cases, the results are not as definitive; the emissions from those plants may cause ambient concentrations to exceed the standards on less frequent occasions,

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or else the modeling technique does not provide as reliable a basis for judging whether a plant is responsible for high concentrations. For the remaining 17 of the 34 plants, the modeling results indicate that the resulting SO_2 concentrations would be expected to remain well below the applicable standards.

Analysis of the work conducted shows that of the seven plants which cause the most severe and persistent exceedances of the air quality standards, five are paper mills. Power plants with relatively short stacks compose a second group of SO_2 sources which cause SO_2 problems.

Other aspects of the study include: a limited model validation analysis which gave satisfactory results; preliminary study of the interactive effects of plumes from contiguous plants; and recommendations for further study of the uncertain cases mentioned above, and cases of multiple contiguous plants.

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Section 1.0

INTRODUCTION

In any case where air quality standards exist, but not emission standards, then determination of compliance can obviously only be made by determination of the existing air quality. Two methods of determining conformance are available to enforcement agencies. One method is to employ an extensive and expensive air monitoring program which can survey the area influenced by a selected plant. The second method is to use a modest modeling program to simulate air quality levels associated with emissions from the plant and the surrounding vicinity. For the purpose of defining whether and where critical problems exist, the second method is the more practical approach. The first step in this approach is to analyze the maximum contributions to air quality levels from selected individual plants which are suspected of having possible compliance problems. A subsequent step, for plants which are shown to have significant contributions to air quality levels, would be to analyze the contributions from any nearby area sources of pollution and any other nearby point sources. The combined air quality levels would then determine the extent to which air quality levels are or are not exceeded.

In EPA Region V, the State of Wisconsin is covered by air quality, not emission, standards: The enforcement arm of Region V, anticipating the possibility of exceedance of air quality standards in connection with SO_2 emissions from a number of point sources (power plants and paper mills) in the state, initiated the present study.

The work described in this report is intended to cover the first step described above, that of modeling air quality levels attributable to selected individual plant emissions.

Section 2.0

OBJECTIVE AND SCOPE

The objective and scope of this program are given in the contract work statement which follows, and the modification instituted later.

The contractor will calculate concentrations from 26 point sources identified by the Region V Enforcement Engineer, by performing the following subtasks:

> Acquire and analyze the necessary and available emission, meteorological, and terrain data. Process the data for input to the models. Determine the extent to which the following should be taken into account: hourly variations in emissions and meteorology, and topographic influences.
>
> Calculate the required concentrations for each source using appropriately selected, EPA-approved models for plume rise and dispersion. Hourly SO_2 concentrations will be calculated to include significant locations around the plant; these will be converted to 3-hour and 24-hour averages and the annual mean, and the highest 20 values of each of the 3- and 24-hour averages will be selected out. For each of these cases the time of day, day of year, meteorological and emission conditions, and location will be determined and analyzed for patterns of occurrence according to those parameters.
>
> Where monitoring data are available, and the source in question is clearly the principal contributor, make comparisons with model predictions for validation purposes. Perform analysis of the validation results as appropriate.
>
> Prepare a report of the findings, with emphasis on the annual mean, 24-hour and 3-hour average data as described above; define special cases where it is determined that further analysis is warranted, such as cases where other contiguous sources may contribute significant concentrations of SO_2, and define the program required to accomplish the second phase of the work as described in the Introduction.

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The scope of this program was subsequently modified as follows:

> "The task scope is amended to include additional survey and reporting requirements in the preliminary modeling analysis of some 55 SO_2 sources. A detailed modeling analysis will then be performed on a lesser number of sources where impact of SO_2 emission on ambient levels is of greatest concern."

By way of explanation, the origin and evolution of the task work is briefly reviewed, as follows: the original assignment and man-hour estimate was based on an initial list of 27 sources (power plants and paper mills) which was derived by visually scanning the 1973 summary printout of point sources of SO_2 in Wisconsin, and selecting the high 27 in terms of annual average SO_2 emissions. Subsequent more intensive review of the detailed emission inventory printouts showed that the selection should be more solidly based, and also showed that there were some 55 sources which should be given at least preliminary modeling analysis to permit consideration of additional factors, particularly stack characteristics, and thus enable a better selection of those sources which should be modeled. This process would then be followed by detailed and specific modeling analysis of the two dozen or so which would then be shown at the top of the new ranking list thus generated.

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Section 3.0

TECHNICAL APPROACH

3.1 SELECTION PROCESS

Table 3-1 gives the basic initial list of sources for this program in columns (4) and (5). This was the starting point, and it was understood that additional sources would be considered after further analysis by the contractor and consultation with the Project Officer. Preliminary study of emission inventory data led to several suggested inclusions early in the program. Further study proceeded, and a new, but still tentative, master list was developed as presented in Table 3-1. In this table are presented all the sources to be considered, divided according to AQCR for convenience, and also divided according to treatment status, but now including additional sources which warranted consideration, at least for initial preprocessing.

In the case of the power plants listed in column (4) of Table 3-1, the procedure was to work initially with reports of the plants which had been or were being modeled by GEOMET and Walden.* These were to be studied and considered in the context of new meteorological, emission, topographical, and monitoring data. This analysis was used to determine whether additional analyses and modeling would be required beyond that of the standardized treatment already given these sources.

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* Power plant modeling had been and was being done for EPA's OAQPS on a nationwide basis using especially selected and standardized input and model data and procedures.

Table 3-1. List of Sources

AQCR		(3) Wisconsin District	SO_2 Sources (File Number) (Av. Tons/Year SO_2) and Status		
(1) Number	(2) Name		(4) Power Plants	(5) Non-Power Plants	(6) Potential Additional Sources
129	Duluth-Superior Interstate	Northwest	(Hibbard-Duluth, Minn.)	Murphy Oil (160012)(8,718)	Bayfront Sta. (020004)(4,917) Flambeau Paper (510001)(3,202)
128	Southeast LaCrosse	West Central	Alma (060001)(28,765) Genoa (630003)(53,157)		Uniroyal (180009)(2,115) Trane (320013)(832) French I. Sta. (320017)(738)
237	Lake Michigan Intrastate	Lake Michigan I and II	Edgewater (600008)(63,014) Pulliam (050013)(58,732)	Badger (380002(2,256) Charmin-Fox River (050003)(16,457) Charmin-East River (050004)(1,114) Fort Howard (050008)(14,887) Thilmany (450011)(5,946)	Manitowoc (360006)(3,301) Niagara Paper (380004)(5,775) Scott Paper (430001)(1,790) American Can (050001)(2,968) Kimberly Clark (450008)(3,969) Menasha (710006)(3,031) Menasha EGP (710008)(2,065) Kohler (600004)(899)
238	North Central Wisconsin Intrastate	North Central	Weston (370003)(20,346)	Owens-Illinois (350004)(5,435) Mosinee (370009)(3,316) Weyerhaeuser (370055)(8,299) Consol.-Biron (720009)(10,022) Consol.-4th Ave. (720010)(11,229) Nekoosa-Pt. Ed. (720011)(8,581) Nekoosa (720012)(8,192)	St. Regis Paper (440001)(7,140) Marshfield Sta. (720001)(3,528) Wausau Paper (370004)(4,914)
068	Metropolitan Dubuque Interstate	Grant County	Stoneman (220002)(8,747) Nelson Dewey (220001)(43,694) (Dubuque, Iowa)		
240	Southern Wisconsin Intrastate	Southern	Blount (130011)(10,186)		Columbia (110007)(done by Walden) Oscar Mayer (130012)(1,947) Badger Army (570008)(1,782)

(Continued)

Table 3-1. List of Sources (Concluded)

AQCR		(3) Wisconsin District	SO_2 Sources (File Number) (Av. Tons/Year SO_2) and Status		
(1) Number	(2) Name		(4) Power Plants	(5) Non-Power Plants	(6) Potential Additional Sources
073	Rockford-Janesville-Beloit Interstate	Rock County	Blackhawk (540012)(560) Rock River (540003)(22,039)		Colt Industries (540001)(680) GMC Assembly (540004)(1,738)
239	Southeastern Wisconsin Intrastate	Southeast	Port Washington (460018)(43,740) Commerce (410010)(3) Valley (410103)(39,653) Oak Creek (N. & S.)(410094)(97,344)	Acme Galvanizing (410360)(5,554)	Anaconda Amer. Brass (300001)(489) Wells Sta. (410009)(361) Cudahy Tanning (410091)(525) Lakeside Sta. (410095)(2,838) Milwaukee Solvay Coke (410077)(1,613) Marquette Cement (410104)(2,604)

The non-power plant sources shown in column (5) of Table 3-1 would be given computer preprocessing treatment to obtain a preliminary determination of the need for further modeling.

Review of detailed 1973 emission inventory printouts for the eight AQCR's in Wisconsin, plus summary printouts of all sources in Wisconsin exceeding 0.25 tons/day, or 25 or 100 tons per year, plus a printout updated to June 30, 1974 containing corrections and additions, resulted in the expansion of the original list of SO_2 sources to include additional suggested plants for a total of 55 plants of possible interest for modeling in this program.

The entire list of 55 plants is included as Table 4.1-1 in Section 4.0. There were thus 55 plants identified in Wisconsin which were to be studied at least to some degree.

The initial processing of data (preprocessing) would then be done for the entire list of 55 plants (see Section 3.2). Processing beyond the preprocessor stage would then be done on a selective basis to be determined either by the expected magnitude of the contribution of SO_2 emissions to the ambient air concentrations, or by the location of the plant; if a plant is located in an area where there are many SO_2 sources, the modeling was to be done at some future time using a regional model which accounts for all such sources.

The preprocessing involves running a computer program (DBT-13) which determines the maximum concentration of SO_2 for all stability classes, and for a variety of wind speeds within each stability class,

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for each stack* at a plant. The output of this program provides input to the principal models which are used for calculating pollutant concentrations under simulated conditions. Results of the selection process are discussed in Section 4.1.

3.2 DATA AND MODELING PROCEDURES

This discussion of modeling and input is intended to give a general description only, in order to facilitate understanding of the discussions of modeling results in Section 4.0. The focus of attention is on model inputs, objectives, and outputs. Additional details are given in Appendix A.

First, a brief explanation of the type of information input to the programs and how each program is used is given to indicate the extent to which this modeling work is tailored to each plant. Figure 3-1 indicates the general flow of the work done for each individual plant.

Section 3.1 describes the initial selection procedure of reviewing the emission inventory compiled by the Wisconsin DNR and selecting the plants with the highest average annual emissions of SO_2. As stated, a list of 55 plants in Wisconsin resulted from that initial search. That list was reviewed with DNR staff and it was concluded that all important SO_2 sources in the state were included. The detailed study of each plant commenced at this point by running the model designated DBT-13.

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* Since this program gives the maximum for each stack, the value shown is in many cases not the highest value for the plant; nor have many other considerations yet been brought in (specific meteorology, e.g.). The concentration figures are thus only very preliminary indications, and are being used only for ranking and scheduling purposes.

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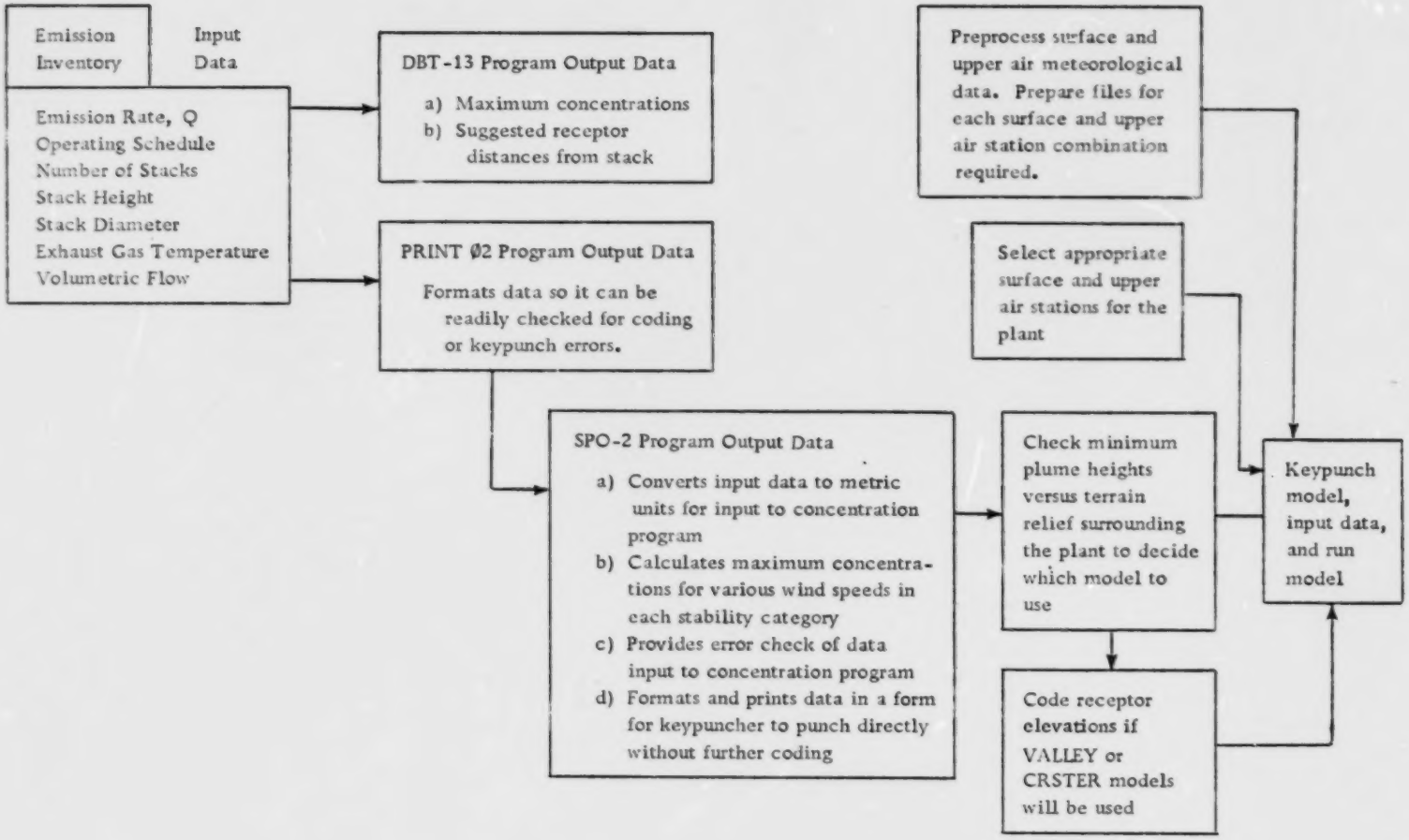
Emission Inventory
Input Data
Emission Rate, Q
Operating Schedule
Number of Stacks
Stack Height
Stack Diameter
Exhaust Gas Temperature
Volumetric Flow
DBT-13 Program Output Data
a) Maximum concentrations
b) Suggested receptor distances from stack
PRINT Ø2 Program Output Data
Formats data so it can be readily checked for coding or keypunch errors.
SPO-2 Program Output Data
a) Converts input data to metric units for input to concentration program
b) Calculates maximum concentrations for various wind speeds in each stability category
c) Provides error check of data input to concentration program
d) Formats and prints data in a form for keypuncher to punch directly without further coding
Preprocess surface and upper air meteorological data. Prepare files for each surface and upper air station combination required.
Select appropriate surface and upper air stations for the plant
Check minimum plume heights versus terrain relief surrounding the plant to decide which model to use
Code receptor elevations if VALLEY or CRSTER models will be used
Keypunch model, input data, and run model

Figure 3-1. Flow of Data Processing

Input to the DBT-13 program includes the following parameters for each stack; emission rate, Q, stack height, H, exhaust gas temperature, T, exhaust gas exit velocity, V, stack diameter, D, and volumetric flow rate, VF. The DBT-13 program computes the distance to maximum concentration for each stack under a variety of wind speeds for each of six atmospheric stability conditions, the plume height for each of those conditions, and the maximum concentration due to each stack. The maximum concentration computed is for those constant and specific conditions of stability class and wind speed - it does not necessarily represent average concentrations for 3- or 24-hour periods. The calculated concentrations are for each individual stack. This program does not combine the concentrations for all stacks at one plant. The total concentrations from all stacks are estimates made from the total DBT-13 data output.

The output also contains suggested distances from the plant where receptor locations should be placed. The procedure for calculating the maximum concentration and distances to suggested receptor locations in the DBT-13 program is identical to the procedure in the SPO-2 program which is described later. Therefore, either the DBT-13 or SPO-2 output can be used to select which model to use for each plant.

The three principal models available are designated CRSMOD, CRSTER, and VALLEY. Descriptions of each of these models are included in Appendix A. The model selection is dependent upon the relation between the minimum plume height calculated and the degree of relief in terrain around the plant. If the terrain is relatively flat, and the difference between the elevation at plant site and the highest terrain

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elevation is less than approximately 10 percent of the minimum plume height, the CRSMOD program is used for modeling. The CRSMOD program does not require reading and coding elevations at receptor locations. If the difference between plant site elevation and the surrounding terrain is greater than 10 percent of the minimum plume height, the CRSTER program is selected.

For the CRSTER model, the elevations of receptor locations are read from topographic maps. Receptor locations for CRSTER are located along radial lines drawn to every 10 degrees of azimuth, hence there are receptors along 36 different lines around the plant. On each line there are 5 distances where receptors are located. Those 5 distances correspond to the distances suggested by the DBT-13 or SPO-2 programs. Those distances are adjusted by the analyst if it appears that a significant topographic feature may be missed otherwise. For CRSTER and CRSMOD, concentrations are calculated for 180 different receptor locations around the plant. If the terrain elevations are higher than the minimum plume rise (i.e., the case where the plume may directly impact on the raised terrain, as for a valley wall or a bluff), the VALLEY program is used. For the VALLEY program, receptor locations are coded at 7 distances from the plant along radial lines which are drawn at 22.5 degree intervals.

The data input to the CRSMOD or CRSTER program is more specific than the input to the DBT-13 program and includes amounts and types of fuels used in the plant and by each boiler, the fuel use capacity for each boiler, the percent use of each boiler, and the boiler-to-stack

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relationships as well as the data which were input to the DBT-13 program. The coding for each plant is input to the PRINT-2 program which prints the information out in a format which allows the data to be easily checked for coding or keypunch errors. After checking the PRINT-2 output for errors, the cards are input to the SPO-2 program which calculates maximum concentrations due to individual stack emissions, calculates suggested distances for receptor locations and converts the SPO-2 input data to metric units as required by the CRSMOD or CRSTER programs. The SPO-2 program formats and prints out the input data to the CRSMOD and CRSTER programs.

The output format of the CRSMOD and CRSTER programs is the same. An example of the CRSTER output is provided in Appendix A. The first page of output lists some of the input data. On the second and third pages, receptor locations and elevations are listed along with stack parameter data, and the monthly variation in the fuel used at the plant is indicated by the heading "seasonal variations by case." The fourth page lists the maximum annual mean concentrations calculated for each of the 180 receptor locations and from that list it picks the highest concentration at any of the locations and prints the appropriate information at the top of the page. The same procedure is done for the 24-hour average concentrations, which follow. The 50 highest 24-hour averages are listed on the sixth page and the 50 highest 3-hour concentrations calculated on the next. That page is titled "maximum computed 3-hour concentration"; in fact, concentrations are calculated for every third hour of the day (when meteorological data is available) and this

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value is a good approximation to the 3-hour maximum. The 24-hour concentrations are averages of the eight "3-hour" concentrations and the annual averages are the average of all concentrations calculated for each point throughout the year.

All information, operational and meteorological, is taken from actual data for the year 1973.

Following the first seven pages, the same kind of information is printed again except that in the second set (not included) the information shows the concentrations which would be expected if the boilers were running at 95 percent of capacity rather than at average conditions as represented in the first set.

The VALLEY model, with its present utilization, computes concentrations for a worst case condition, e.g., a light wind (2.5 m/sec) blowing continuously in one direction for six hours within a 24-hour period. The VALLEY model output (Appendix A) lists input data on the first three pages. The next two show the calculated concentrations at each receptor location due to individual stacks and the combined concentrations are printed on the sixth page. The maximum concentration for any receptor location is printed on the seventh. Receptor elevations relative to the plant are shown next, and the last eight pages (not included) repeat the information for the maximum load case when the boilers would be operating at full load.

As regards input data and program adjustments, the following comments apply. 1973 fuel consumption and plant operating characteristic data for 24 of the power plants included in the list of 55 SO_2 sources

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were obtained from the Federal Power Commission (FPC). The data from FPC provides the amount of fuel used at each generating station on a monthly basis. Boiler operation schedule and stack parameter data are also available from the FPC Form 67. Comparison of the 1973 fuel use data with the 1971 or 1972 fuel use data that was used in previous modeling work for these plants indicates that there are significant differences between years, and that modeling those plants again with 1973 data is therefore warranted.

The programs used for modeling the plants, and the programs required to prepare the meteorological data used in the concentration prediction programs required some modifications due to the form of the meteorological data which was used for this task. The meteorological programs which process the surface observation data had to be changed to accept observed data every third hour instead of for every hour as they had been used for previously. This was necessary because of the type of data which is available from the National Climatic Center (NCC). NCC routinely prepares the synoptic observations (every third hour) for recording on magnetic tape, and the cost and time to delivery for this information are quite acceptable. If, however, the surface observations for each hour are required, NCC must specially prepare that data on magnetic tape, and the cost and time to delivery (3 months after receipt of order) were not acceptable to the constraints of this program.

The program which calculates mixing heights from upper air sounding data also had to be modified to accommodate those occasions when the upper air sounding data was missing. In previous uses of this

program, all expected data were available on the data tape and the missing data problem was not encountered.

The concentration prediction program had to be modified to accept meteorological data for every third hour, and to make concentration calculations for those hours only. Also, some changes were made to tailor the output more specifically to the needs of this task. Finally, modifications were made which enable the computer models to make concentration calculations for stacks whose exhaust temperatures are not significantly higher than ambient atmospheric temperatures.

3.3 SPECIAL CONSIDERATIONS

Although these models have been carefully designed for and by EPA to represent pollutant dispersion as realistically as possible, special attention must be paid to the possibility of the influence of any special factors, as follows.

All available and relevant data is of course considered. These data, which were sought out via the Project Officer and the Wisconsin State Department of Natural Resources, included: consideration of other sources in the area; measured air quality data for validation purposes; known or suspected downdraft of fumigation conditions; unique nearby terrain features; nearby land use patterns and population distributions; as specific and up-to-date operational data for the source as was available; specific meteorological studies for the area; and any other studies and findings by other investigations.

Each of these considerations was brought to bear in the findings of Sections 4.0 and 5.0, and adjustments made to the results where justified. If the new information represented a significant change in the model input, partial or complete additional model runs were made, as deemed necessary. These final results represent the product of the program in terms of the best estimates of the impact on the individual sources on air quality.

Section 4.0

RESULTS

4.1 RESULTS OF SELECTION PROCESS

Because the process of determining which plants should receive complete modeling occupied an important part of the program, and because the stepwise selection process tended to make significant changes in the list each time, it is considered worth documenting the results. It is especially interesting because it dramatizes the misleading impressions one may get from emissions data alone, or even from simplified modeling estimates.

Table 4.1-1 presents the second list developed, in which the initial 26 sources had been expanded to 55, ranked by annual average SO_2 emissions. A selection for modeling from this list would have picked the top two dozen or so.

Table 4.1-2 presents the results of the next phase. All sources for which adequate data could be found were subjected to the preliminary type of DBT-13 modeling (Section 3.2) and ranked according to the results for atmospheric stability class four, as a first approximation to the maximum 24-hour average concentration. The rank order from Table 4.1-1 is included in the next-to-last column in order to show the changes which have taken place. The sources to be given complete modeling treatment were taken as the top 34 of this list. The logic here was to follow the conservative line of selecting all sources whose estimated 24-hour average figure was at

TABLE 4.1.1 SO-2 SOURCES RANKED ON ANNUAL AVERAGE SO-2 EMITTED

PLANT NAME	LOCATION	AQCR	FILE NO.	AVG. ANN. EMISSIONS (TON/YEAR)	RANK ON AVG. ANN. EMISSIONS
OAK CREEK GEN.(NES)OAK CR		239	410094	97344	1
EDGEWATER GEN STA SHEBOYG		237	600008	63014	2
PULLIAM GEN.STA.GREEN BAY		237	050013	58732	3
GENOA GEN.STA.	GENOA	128	630003	53157	4
PORT WASH.GEN.STA.PORT WA		239	460016	43740	5
NELSON-DEWEY STA-CASSVILL		068	220001	43694	6
VALLEY GEN.STA. MILWAUKEE		239	410103	39653	7
ALMA GEN STA.	ALMA	128	060001	28765	8
ROCK RIVER GEN STA BELOIT		073	540003	22039	9
WESTON GEN.STA. ROTHSCHIL		238	370003	20346	10
CHARMIN PAP.FOX RGREENBAY		237	050003	16457	11
FORT HOWARD PAP.GREEN BAY		237	050008	14887	12
BLOUNT STGEN STA. MADISON		240	130011	10186	13
CONSOLIDATED PAP.MISC PAP		238	720010	11229	14
CONSOLIDATED PAP.WISCON		238	720009	10022	15
STONEMAN GEN ST.CASSVILLE		068	220002	8747	16
MURPHY OIL	SUPERIOR	129	160012	8718	17
NEK-ED PAPER CO PORT EDW		238	720011	8581	18
WEYERHAUSER	ROTHSCHILD	238	370055	8249	19
NEK-ED PAPER CO NEKOOSA		238	720012	8192	20
ST.REGIS PAPERRHINELANDER		238	440001	7140	21
THILMANY PAPER KAUKAUNA		237	450011	5946	22
NIAGARA PAPER	NIAGARA	237	380004	5775	23
OWENS-ILLINOIS	TOMAHAWK	238	350004	5435	24
BAYFRONT GEN.STA. ASHLAND		129	020004	4917	25
WAUSAU PAPER	BROKAW	238	370004	4914	26
KIMBERLY CLARK KIMBERLY		237	450008	3969	27
MARSHFIELD STA. MARSHFIE		238	720001	3528	28
MOSINEE PAPER CO MOSINEE		238	370009	3316	29
MANITOWOC PUB.UT.MANITOWO		237	370006	3301	30
FLAMBEAU PAPER PARK FALLS		129	510001	3202	31
MENASHA CORP.	MENASHA	237	710006	3031	32
AMERICAN CAN	GREEN BAY	237	050001	2968	33
LAKESIDE GEN.STA.MILWAUKE		239	410095	2838	34
MARQUETTE CEMENT MILWAUKE		239	410104	2604	35
BADGER PAPER	PESHTIGO	237	380002	2256	36
UNIROYAL INC	EAU CLAIRE	128	180009	2175	37
MENASHA ELECGWATR MENASHA		237	710008	2065	38
OSCAR MEYER	MADISON	240	130012	1947	39
SCOTT PAPER	OCONTO FALLS	237	430001	1790	40
BADGER ARMY AMMUN BARABOO		240	570008	1782	41
GMC ASSEMBLY JANESVILLE		073	540004	1738	42
MILWAUKEE SOLVAY MILWAUKE		239	410077	1613	43
CHARMIN PAP.E.RIVGREENBAY		237	050004	1114	44
KOHLER CO.	KOHLER	237	600004	899	45
TRANE CO.	LACROSSE	128	320013	832	46
COLT INDUSTRIES BELOIT		073	540001	680	47
BLACKHAWKGEN.STA. BELOIT		073	540012	560	48
CUDAHY TANNING	CUDAHY	239	410091	525	49
AMER ANAC. BRASS KENOSHA		239	300001	489	50
WELLS GEN.STA. MILWAUKEE		239	410009	361	51
FRENCH I.GEN STA LACROSSE		128	320017	41	52
ACME GALVANIZING MILWAUKE		239	410360	34	53
COMMERCE GEN STA MILWAUKE		239	410010	3	54
COLUMBIA GEN STA PORTAGE		240	110007		55

TABLE 4.1.2 SO-2 SOURCES RANKED ON CONCENTRATION DETERMINED FROM PRELIMINARY MODELING.*

PLANT NAME	LOCATION	AQCR	FILE NO.	AVG. ANN. EMIS-SIONS (TON/YEAR)	ORT-13 CONC.CALC. ALL STACKS STAR.STAR = 4	ORT-13 CONC.CALC. ALL STACKS STAR.STAR ≠4	RANK ON AVG. ANN. EMIS-SIONS	RANK ON ORT 13
WAUSAU PAPER	BROKAW	238	370004	4914	24280	24280	26	1
SCOTT PAPER	OCONTO FALLS	237	430001	1790	10100	10800	40	2
FLAMBEAU PAPER	PARK FALLS	129	510001	3202	5406	5546	31	3
BADGER PAPER	PESHTIGO	237	380002	2256	4000	5000	36	4
CUDAHY TANNING	CUDAHY	239	410091	525	2478	2594	49	5
NEK-ED PAPER CO	PORT EDW	238	720011	8581.	2000	3300	18	6
AMERICAN CAN	GREEN BAY	237	050001	2968	1354	2139	33	7
WEYERHAUSER	ROTHSCHILD	238	370055	8299	1271	2472	19	8
STONEMAN GEN ST.	CASSVILLE	068	220002	8747	1166	2380	16	9
CONSOLIDATED PAP.	BIRON	238	720009	10022	710	1832	15	10
ALMA GEN STA.	ALMA	128	060001	28765	669	1860	8	11
ST.REGIS PAPER	RHINELANDER	238	440001	7140	624	761	21	12
TRANE CO.	LACROSSE	128	320013	832	480	560	46	13
PULLIAM GEN.STA.	GREEN BAY	237	050013	58732	435	2898	3	14
MENASHA ELEC&WATR	MENASHA	237	710008	2065	396	549	38	15
MOSINEE PAPER CO	MOSINEE	238	370009	3316	375	864	29	16
THILMANY PAPER	KAUKAUNA	237	450011	5946	363	940	22	17
BAYFRONT GEN.STA.	ASHLAND	129	020004	4917	350	738	25	18
CHARMIN PAP.	FOX RGREENBAY	237	050003	16457	349	442	11	19
OAK CREEK GEN.	(NES)OAK CR	239	410094	97344	344	930	1	20
LAKESIDE GEN.STA.	MILWAUKE	239	410095	2838	327	1576	34	21
WESTON GEN.STA.	ROTHSCHIL	238	370003	20346	324	1174	10	22
CHARMIN PAP.	E.RIVGREENBAY	237	050004	1114	317	656	44	23
ROCK RIVER GEN STA	BELOIT	073	540003	22039	258	974	9	24
OWENS-ILLINOIS	TOMAHAWK	238	350004	5435	250	620	24	25
EDGEWATER GEN STA	SHEBOYG	237	600008	63014	234	590	2	26
MENASHA CORP.	MENASHA	237	710006	3031	229	418	32	27
MARSHFIELD STA.	MARSHFIE	238	720001	3528	208	450	28	28
CONSOLIDATED PAP.	WISC RAP	238	720010	11229	198	598	14	29
VALLEY GEN.STA.	MILWAUKEE	239	410103	39653	166	1056	7	30
OSCAR MEYER	MADISON	240	130012	1947	164	296	39	31
MARQUETTE CEMENT	MILWAUKE	239	410104	2604	164	368	35	32
BLOUNT STGEN STA.	MADISON	240	130011	10186	164	296	13	33
NIAGARA PAPER	NIAGARA	237	380004	5775	154	464	23	34
NELSON-DEWEY STA-	CASSVILL	068	220001	43694	130	365	6	35
PORT WASH.GEN.STA.	PORT WA	239	460016	43740	124	468	5	36
ACME GALVANIZING	MILWAUKE	239	410360	34	119	133	53	37
AMER ANAC. BRASS	KENOSHA	239	300001	489	108	268	50	38
MANITOWOC PUB.UT.	MANITOWO	237	370006	3301	104	391	30	39
FORT HOWARD PAP.	GREEN BAY	237	050008	14887	104	363	12	40
GENOA GEN.STA.	GENOA	128	630003	53157	98	380	4	41
GMC ASSEMBLY	JANESVILLE	073	540004	1738	93	300	42	42
UNIROYAL INC	EAU CLAIRE	128	180009	2175	93	266	37	43
COLT INDUSTRIES	BELOIT	073	540001	680	90	150	47	44
NEK-ED PAPER CO	NEKOOSA	238	720012	8192	60	176	20	45
KOHLER CO.	KOHLER	237	600004	899	48	124	45	46
WELLS GEN.STA.	MILWAUKEE	239	410009	361	36	141	51	47
BLACKHAWKGEN.STA.	BELOIT	073	540012	560	24	72	48	48
FRENCH I.GEN STA	LACROSSE	128	320017	41	18	38	52	49
COMMERCE GEN STA	MILWAUKE	239	410010	3	3	12	54	50
COLUMBIA GEN STA	PORTAGE	240	110007		2	6	55	51

* These concentration calculations should not be used as absolute representations of expected concentrations from these sources. The modeling technique is quite limited in application, and is used only as a processing step. Further, the input data was not carefully rechecked for these runs, as it subsequently was for the final runs (see text).

least half the air quality standard value of 365 micrograms per cubic meter. Consideration was also given to the "stability-other-than-four" calculation as a preliminary estimate of the 3-hour maximum value.

The selected list of 34 was then modeled according to the more extensive procedures described in Section 3.2, and ranked anew according to the maximum 24-hour average concentrations, with the results given in Table 4.1-3. Again in this table the ranking numbers from the previous tables are given in the second and third columns from the end, and again we note the shifting of position. The last column is the final ranking. In particular, it should be pointed out that, if the selection had been made on the basis of emissions, for example, a number of sources would have been modeled which did not need to be, and vice versa.

As mentioned in the footnote to Table 4.1.2, the input data for all of the selected 34 plants in that table were carefully rechecked; as a result of this recheck, some input data changes were made, so that comparisons of concentrations in Table 4.1.2 with those in Table 4.1.3 are not warranted. The final results presented in Table 4.1.3 are the only results which should be considered representative of the plants, and the only ones which should be used for analysis.

As a final comment, some clarification of the predicted concentrations for maximum load conditions are useful, in order to clarify what may seem to be discrepancies between nominal load and maximum load predictions in Table 4.1.3. In some instances maximum load concentrations may be less than the nominal load predictions. This may result from several factors; for example, variations in the exhaust velocity or temperature

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Table 4.1.3 SO-2 Sources Ranked on Predicted Maximum 24-Hour Concentrations

Plant			Average Annual Emissions (Ton/Year)	Model Predictions					Rank On		
				Nominal Load			Maximum Load				
Name/Location	AQCR	File No.		Annual Mean	24-Hour Avg.	3-Hour Avg.	24-Hour Avg.	3-Hour Avg.	Average Annual Emissions	DBT-13	Final Modeling Procedures
Alma Generating Station/Alma	128	060001	28765		6332		7980		8	11	1
Thilmany Paper Company/Kukauna	237	450011	5946	21	1957	15660	2200	17610	22	17	2
Badger Paper Company/Peshtigo	237	350002	2256	98	1744	6490	1744	6490	36	4	3
Stoneman Generating Station/Cassville	068	220002	8747		1718		1624		16	9	4
Flambeau Paper/Park Falls	129	510091	3202	21	1377	2411	523	1114	31	3	5
Nekoosa-Edwards Paper Company/Port Edw.	238	720011	8581	103	1203	5333	1203	5333	18	6	6
Mosinee Paper Company/Mosinee	238	370009	3316	57	1119	4363	3045	13750	29	16	7
Charmin Paper, Fox River/Green Bay	237	050003	16457	30	691	5530	691	5530	11	19	8
American Can/Green Bay	237	050001	2968	40	554	2817	554	2817	33	7	9
Pulliam Generating Station/Green Bay	237	050013	58732	22	487	1898	653	2602	3	14	10
Scott Paper/Oconto Falls	237	430001	1790		461		449		40	2	11
Marquette Cement/Milwaukee	239	410104	2604	19	452	902	1899	902	35	32	12
Bayfront Generating Station/Ashland	129	020004	4917	19	401	2810	464	2343	25	18	13
Edgewater Generating Station/Sheboygan	237	600008	63014	12	384	1209	590	2095	2	26	14
Rock River Generating Station/Beloit	073	540003	22039	15	311	1298	268	1208	9	24	15
Wausau Paper/Brokaw	238	370004	4914		281		285		26	1	16
Consolidated Paper/Biron	238	720009	10022	18	279	1567	254	1442	15	10	17
Oak Creek Generating Station/Oak Creek	239	410094	97344	6	224	1223	389	2206	1	20	18
Weston Generating Station/Rothschild	238	370003	20346		214		388		10	22	19
St. Regis Paper/Rhinelander	238	440001	7140	16	211	743	212	711	21	12	20
Blount Street Generating Station/Madison	240	130011	10186	7	180	898	314	1097	13	33	21
Valley Generating Station/Milwaukee	239	410103	39653	5	154	1080	225	1547	7	30	22
Owens-Illinois/Tomahawk	238	350004	5435	6	150	696	189	718	24	25	23
Menasha Corporation/Menasha	237	710006	3031	9	146	679	181	845	32	27	24
Marshfield Station/Marshfield (Wildwood)	238	720091	3528	6	136	621	68	602	28	28	25
Oscar Meyer/Madison	240	130012	1947	4	132	414	558	1818	39	31	26
Menasha Electric & Water/Menasha	237	710008	2065	8	128	349	1007	2480	38	15	27
Niagara Paper/Niagara	237	380004	5775		123		156		23	34	28
Consolidated Paper/Wisconsin Rapids	238	720010	11229	4	118	773	109	710	14	29	29
Blackhawk Generating Station/Beloit	073	540012	560	2	98	249	130	482	48	48	30
Weyerhauser/Rothschild	238	370055	8299		92		149		19	8	31
Charmin Paper, East River/Green Bay	237	050004	1114	6	90	612	225	1528	44	23	32
Trane Company/Lacrosse	128	320013	832		43		268		46	13	33
Nekoosa-Edwards Paper Company/Nekoosa	238	720012	8192	1	37	195	40	214	20	45	34

which result from the change in operating conditions can cause this. Alternatively, in some cases data were not available to make an accurate estimate of the use of the boilers at a particular plant. The maximum load emission rate and exhaust gas parameters are calculated by the DBT-13 program, which makes the assumption that a boiler operates at 95 percent of capacity under maximum load. If the operating capacity of a boiler at nominal load is not accurate, the maximum load data calculated by DBT-13 could be misleading; however the data input to the nominal load calculations are accurate to the degree that the emission inventory is accurate. In general then the nominal load predictions are reliable whereas the maximum load predictions for the paper companies must be considered with strong reservations because boiler capacity data for the paper companies was not available. Boiler capacity data was available for the power plants and maximum load predictions for them are considered reliable.

4.2 VALIDATION

4.2.1 Procedures and Limitations

The program calls for such validation as may be feasible, where monitoring data are available, and where the source in question is clearly the principal contributor.

It should be made clear at the outset that validation conducted under these limited circumstances (i.e., with neither monitoring nor modeling designed and conducted explicitly for validation purposes) should not be expected to give precise and unqualified results. Also, a day-by-day, station-by-station validation is beyond the resources and intent of

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this program, and probably not warranted in view of the nature and extent of the monitoring data.

Modeling can provide a good estimate of, say, the 24-hour average concentrations, at any desired distance and direction from a source of interest. In this case the complete modeling has been done for all 36 directions (every 10 degrees) and at 5 distances in each direction, chosen so as to insure that the locations of maxima are included.

Conversely, monitoring is characteristically done at only one location, or a small number of locations at most, and in the cases of concern here, the azimuth and distance of the monitor from a source of interest will have no particular relationship to the regions of anticipated maxima from that source where calculations are made. Additionally, in most cases samples are not available for all days of a year, but rather a relatively small number of days, such as 5 to 10 percent of the total number possible. The situation is complicated by the fact that in all cases where monitors and sources are contiguous, there is more than one source (in some cases quite a few), and all are located in or near towns or cities with SO_2 levels arising from other sources.

Thus only approximate or general validation may be sought by comparing, for those cases where monitors and sources are contiguous and data are available for the desired data year (1973), the mean and maximum values measured and predicted. The predicted annual mean should ordinarily be approximately equal to or less than the observed value, due to the existence of other sources not accounted for in the model. The predicted maximum 24-hour average value should equal or exceed the observed

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maximum, because of the likelihood that the maximum will not have been included in the limited number of samples available.

The subsequent discussion of validation should be read with the above limitations in mind.

4.2.2 Air Quality Data Base for Validation

Members of the Wisconsin DNR staff had advised that all monitoring data that might be useful in validation had been entered into EPA's SAROAD system. Accordingly SO_2 data was requested and obtained from SAROAD representing all years and all stations in Wisconsin. The validation was focused on the modeling year of 1973, and sorting the SAROAD to match cases where monitors were contiguous to sources led to a selection of six communities out of fifteen; further screening had to be applied to eliminate those areas which had a large number of sources and/or the likelihood of significant other sources of SO_2. This type of validation analysis is beyond the scope of the present study. The screening dropped out Milwaukee/Waukesha, and put in doubt Green Bay/DePere and Menasha, leaving Beloit (one station), LaCrosse (two), and Madison (seven).

4.2.3 Results

Beloit: The one monitoring station (50 readings for 1973) is well inside the innermost calculating distance for the Blackhawk plant, which means that the majority of the time the major portion of the pollutant cloud will be touching down at distances well beyond the location of the monitor. The highest annual average from the plant is expected

to occur at some 6-8 km southeast of the plant, and is only about 2 $\mu g/m^3$ compared to the close-in observation of an annual average value of 14 $\mu g/m^3$. This would imply that there are other sources, probably area sources, contributing to the average. The highest 24-hour maxima from Blackhawk all occur at distances of 4-8 km from the plant, and thus are not likely to be associated with the observed maximum of 141 $\mu g/m^3$.

The Rock River plant, however, some 8 km north on the Rock River shows an average value of 3 to 6 $\mu g/m^3$ in the area of the monitor which could thus be a significant contributor to the observed average. Also, the Rock River calculations show 24-hour maxima of 120-140 $\mu g/m^3$ in the area of the monitor. The calculations thus indicate that a significant part of the observed annual average, and probably the entire observed maximum, at the monitor near the Blackhawk plant, is attributable to the Rock River plant some distance away.

LaCrosse: Two monitoring stations in LaCrosse are some 1.5-2.5 km generally northwest of the Trane plant. The French Island station, some 4 km northwest, is not considered relevant because of its low emission rate. The monitors (81 and 111 observations) recorded means of 9 and 6 $\mu g/m^3$, respectively, and corresponding maxima of 102 and 28 $\mu g/m^3$. The highest predicted maximum values in that direction are in the range of 45-55 $\mu g/m^3$, which are in the mid-range of the observations; the VALLEY model, used in this case, does not generate annual average values, so that no comparison can be made.

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Madison: This is a more complex case, with two significant sources several miles apart (Blount plant and Oscar Meyer) and seven monitoring sites ranging in distance from a few hundred meters to 2-3 km from each plant. The observed annual mean values range from lows of 7, 8, and 9 $\mu g/m^3$ to intermediate levels of 12, 13, and 22 $\mu g/m^3$, to a high of 41 (to be brought into question later). All the predicted averages at these locations (summed from the two plants) are quite low, ranging from 1-2 up to about 5 $\mu g/m^3$. The implication is of a significant general level of emissions from unspecified, area-type sources. On the other hand, the 24-hour maxima for these stations (save one) range from 25-50 up to 100-125 $\mu g/m^3$, a range which is comfortably straddled by the predicted range of from about 20-140 $\mu g/m^3$. The one exception is a station (the same as the one at which the average of 41 $\mu g/m^3$ was recorded), which showed a single value of 433 $\mu g/m^3$; this is not only inconsistent with all the predictions, but also with all the other observations as well, including the others recorded at that same monitoring site. Thus that value is suspect, and is considered unrepresentative of air quality, and thus inappropriate for validation.

Green Bay, Menasha, and Milwaukee: These areas, because of the number of sources involved, would normally call for a more in-depth validation analysis; however it is not clear that this effort is warranted, and in any event it is beyond the resources of this program. Some comments are in order, however, as a result of a cursory examination of the available information.

For Milwaukee, there is only one station shown recording 24-hour averages of SO_2 in 1973, and that parameter is likely to be heavily impacted by the contiguous source concept; accordingly it is not treated here. There are four stations recording the results of monitoring of 1-hour values of SO_2, which are comparable in nature to the modeled 1 to 3 hour predictions, and are not likely to be influenced by contiguous sources. A very coarse examination of the predictions from nearby major sources shows a number of 1-hour maxima in the range of 400-900 $\mu g/m^3$ in the vicinity of the Marquette Cement plant, and 800-1000 $\mu g/m^3$ from Valley Station; the highest 1-hour observations from three of the four stations range from about 800 to a little over 4000 $\mu g/m^3$.

In Menasha, the single monitor is quite close to the two Menasha plants; the observed mean is in the range of 15-20 $\mu g/m^3$, and the two plants have predicted means in that area of about 6 $\mu g/m^3$ and about 4 $\mu g/m^3$ respecitvely, for a total of about 10 $\mu g/m^3$. This would imply some additional unspecified area-type sources in the area (Kimberly Clark and Thilmany are too far up the Fox River to have any influence). The recorded maximum is 109 $\mu g/m^3$, while the respective predictions are in the range of about 70 to 120, and 40 to 90 $\mu g/m^3$.

At Green Bay, which has four large sources within a distance of a little over a mile, and four monitoring sites in the vicinity, the situation is too complex to risk an abbreviated analysis.

4.2.3 Summary

These rough validation examinations show no significant inconsistencies, but rather, in general demonstrate a comfortable degree of

consistency which lends confidence to the general nature of the modeling results. Attention is invited again to the discussion of Section 4.2.1 regarding the limitations of validation analyses done in this fashion.

4.3 RESULTS FOR EACH SELECTED SOURCE

A total of 34 plants were modeled and the concentrations predicted from the modeling ranged from very high to values well below the established air quality standards. The predicted concentrations and the number of times the standards may be exceeded are summarized in Table 4.3.1. The plants are entered in Table 4.3.1 in alphabetical order by plant name.

Pertinent stack data for each stack of every plant modeled is also presented in Table 4.3.1.

The stack data in the table have been rounded off and is therefore slightly different than the model input. The exact values of the model input data are printed on the output pages of each plant's run. The rounding off has caused some values of the emission rate and exit velocity to be listed as zero in Table 4.3.1. The stack height data is given to the nearest whole meter, the exit velocity to the nearest meter per second, the exhaust gas temperature to the nearest degree and the emission rate is given to the nearest one-tenth of a gram per second. Stack data are given for nominal load and maximum load. The values for these two conditions will be the same when there was no information available to indicate they were different. Usually, only the information for the power plants was detailed enough to differentiate between nominal and maximum load conditions.

Table 4.3.1. Summary of Stack Input Data and Predicted Concentrations Stack Parameters

Plant Name	Stack Height (meters)	Nominal Load			Maximum Load			Concentrations								
								Nominal Load					Maximum Load			
									24-Hour		3-Hour			24-Hour	3-Hour	
		Exit Velocity (m/sec)	Exhaust Temp. (°K)	Emission Rate (gms/sec)	Exit Velocity (m/sec)	Exhaust Temp. (°K)	Emission Rate (gms/sec)	Max. Annual ($\mu g/m^3$)	Max. ($\mu g/m^3$)	Number Over Standard	Max. ($\mu g/m^3$)	Number Over Standard	Max. Annual ($\mu g/m^3$)	Max. ($\mu g/m^3$)	Number Over Standard	Max. ($\mu g/m^3$)	Number Over Standard
ALMA Gen. Sta.	64	41	430	208	41	430	262		6332					7980			
	64	65	420	412	65	420	522										
	58	59	418	443	59	418	536										
American Can	69	18	444	13.1	18	444	118.6	40	554	29	2817	>50	70	554	>50	2817	>50
	27	15	322	0.1	15	322	0.1										
	35	10	305	6.5	10	305	6.5										
	30	5	373	80.6	5	373	80.6										
Badger Paper	46	3	525	1.6	3	525	1.6	98	1744	>50	6490	>50	185	1744	>50	6490	>50
	16	7	450	11.9	7	450	29.9										
	16	7	450	11.9	7	450	29.9										
	29	5	305	4.4	5	305	4.4										
	24	0	322	12.5	0	322	12.5										
	26	0	322	12.4	0	322	12.4										
	24	1	322	25.1	1	322	25.2										
	24	1	322	19.2	1	322	19.2										
	26	14	338	2.1	14	338	2.1										
Bayfront Gen. Sta.	52	8	[illegible]	2.8	16	439	18.2	19	401	2	2810	11	64	464	3	2343	15
	52	8	408	6.8	16	439	18.2										
	43	5	439	30.9	10	466	70.5										
	43	5	439	47.7	10	466	84.6										
	59	12	400	56.0	22	430	225.6										
Blackhawk Gen. Sta.	69	9	430	59.8	18	436	395.7	2	98	0	249	0	10	130	0	482	0
Blount Gen. Sta.	27	9	533	0.0	17	594	7.9	7	200	0	898	0	38	314	0	1097	0
	28	8	422	0.0	15	450	10.5										
	76	4	409	48.1	8	435	319.3										
	76	6	466	7.9	10	509	200.6										
	76	12	405	106.9	18	416	282.5										
	76	12	405	128.7	18	416	282.5										
Charmin-East River	43	2	455	15.9	2	455	39.6	6	90	0	612	0	30	225	0	1528	3
	43	2	455	15.9	2	455	39.6										
Charmin-Fox River	92	31	339	480.2	31	339	629.7	30	691	22	5530	>50	50	691	>50	5530	>50
	21	2	305	20.7	2	305	20.7										
	18	13	394	0.1	13	394	0.1										
	18	24	394	0.1	24	394	0.1										
	18	12	411	0.7	12	411	0.7										
Consolidated Paper - Biron	52	14	483	92.0	14	483	124.4	18	279	0	1567	13	35	254	0	1442	2
	53	12	327	195.5	12	327	176.3										

(Continued)

Table 4.3.1. Summary of Stack Input Data and Predicted Concentrations Stack Parameters (Continued)

Plant Name	Stack Height (meters)	Nominal Load			Maximum Load			Concentrations								
								Nominal Load					Maximum Load			
									24-Hour		3-Hour			24-Hour	3-Hour	
		Exit Velocity (m/sec)	Exhaust Temp. (°K)	Emission Rate (gms/sec)	Exit Velocity (m/sec)	Exhaust Temp. (°K)	Emission Rate (gms/sec)	Max. Annual ($\mu g/m^3$)	Max. ($\mu g/m^3$)	Number Over Standard	Max. ($\mu g/m^3$)	Number Over Standard	Max. Annual ($\mu g/m^3$)	Max. ($\mu g/m^3$)	Number Over Standard	Max. ($\mu g/m^3$)	Number Over Standard
Consolidated Paper Wisc. Rapids	65	11	466	157.8	11	466	147.8	4	118	0	773	0	12	109	0	710	0
	62	11	466	157.8	11	466	141.0										
	91	22	422	4.4	22	422	10.2										
Edgewater Gen. Sta.	29	5	436	132.3	10	441	491.2	12	384	2	1209	0	39	590	6	2095	9
	41	18	408	323.0	24	411	545.8										
	74	19	437	1325.2	25	441	1512.4										
Flambeau Paper	21	24	454	1.6	24	454	13.8	21	1377	29	2411	>50	33	528	4	1114	0
	58	2	464	0.8	2	464	3.1										
	41	7	430	22.2	7	430	9.0										
	31	8	511	2.8	8	511	2.8										
	21	11	373	19.5	11	373	19.5										
	21	11	373	19.5	11	373	19.5										
	21	11	373	39.1	11	373	39.1										
	13	3	305	4.8	3	305	4.8										
Marquette Cement	46	10	353	88.9	10	353	88.9	19	452	1	902	0	85	452	1	854	0
Menasha Corp.	37	10	433	86.9	10	433	108.2	9	146	0	679	0	27	181	0	845	0
Menasha Elec. & Water	26	3	494	3.6	3	494	26.1	8	128	0	349	0	122	1007	48	2480	>50
	26	3	494	3.0	3	494	26.1										
	26	17	447	17.6	17	447	37.4										
	28	17	444	35.0	3	444	71.6										
Mosinee Paper	28	7	589	18.8	7	589	18.2	57	959	>50	4363	>50	539	3045	>50	13570	>50
	28	7	589	18.0	7	589	17.2										
	28	7	589	15.4	7	589	14.3										
	28	7	589	1.2	7	589	1.0										
	31	5	436	35.1	6	436	23.9										
	32	9	589	1.6	9	589	219.7										
	38	10	411	4.7	10	411	5.0										
Nekoosa-Edwards	65	17	477	234.5	17	477	258.7	0.9	37	0	195	0	3	40	0	215	0
Niagara Paper	47	14	477	124.6	14	477	156.7		123					156			
	47	7	444	41.0	7	444	52.2										
Nekoosa-Edwards	66	8	450	11.8	8	450	46.6	103	1203	>50	5333	>50	203	1203	>50	5333	>50
	30	3	355	65.0	3	355	65.0										
Fort Edwards	30	69	366	195.0	69	366	195.0										

(Continued)

Table 4.3.1. Summary of Stack Input Data and Predicted Concentrations Stack Parameters (Continued)

Plant Name	Stack Height (meters)	Nominal Load			Maximum Load			Concentrations								
								Nominal Load					Maximum Load			
									24-Hour		3-Hour			24-Hour	3-Hour	
		Exit Velocity (m/sec)	Exhaust Temp. (°K)	Emission Rate (gms/sec)	Exit Velocity (m/sec)	Exhaust Temp. (°K)	Emission Rate (gms/sec)	Max. Annual ($\mu g/m^3$)	Max. ($\mu g/m^3$)	Number Over Standard	Max. ($\mu g/m^3$)	Number Over Standard	Max. Annual ($\mu g/m^3$)	Max. ($\mu g/m^3$)	Number Over Standard	Max. ($\mu g/m^3$)	Number Over Standard
Oak Creek Gen. Sta.	107	21	380	678.0	21	380	1203.6	6	224	0	1223	0	36	389	2	2206	29
	107	22	382	780.0	22	382	1225.2										
	138	22	383	961.6	22	383	2494.4										
	170	31	389	1923.6	31	389	2855.1										
	6	12	741	0.1	12	741	27.6										
Oscar Meyer	37	7	472	36.4	7	472	73.7	4	132	0	414	0	48	588	7	1828	2
	37	7	472	19.0	7	472	73.7										
	37	9	472	0.5	9	472	87.1										
Owens-Illinois	16	11	505	0.8	11	505	9.0	6	150	0	696	0	19	189	0	718	0
	37	12	519	47.1	12	519	72.9										
	37	8	425	106.8	8	425	94.5										
	34	9	429	6.5	9	429	15.8										
J. P. Pulliam Gen. Sta.	56	1	415	0.0	3	429	12.2	22	487	5	1898	>50	60	653	38	2602	>50
	56	3	395	87.6	9	439	101.9										
	56	4	431	95.3	6	453	235.6										
	56	5	434	200.0	6	466	439.4										
	72	6	416	341.0	7	445	534.9										
	72	3	422	343.0	4	438	580.8										
	72	6	439	618.2	6	439	866.1										
Rock River Gen. Sta.	76	10	394	278.4	13	394	382.1	15	311	0	1298	0	28	268	0	1208	0
	76	6	389	356.2	13	394	382.1										
St. Regis Paper Co.	61	12	491	123.9	12	491	156.6	16	211	0	743	0	43	212	0	711	0
	61	19	444	69.7	19	444	142.6										
	51	4	448	0.6	4	448	0.6										
	18	9	364	25.0	9	364	25.0										
Scott Paper Co.	67	8	436	180.3	8	436	180.3		461					449			
	15	0	378	6.1	0	378	6.1										
	15	0	378	6.1	0	378	6.1										
	15	0	378	4.6	0	378	4.6										
	15	0	378	5.4	0	378	5.4										
	8	1	305	1.5	1	305	1.5										
	18	3	405	1.3	3	405	2.6										
Stoneman Gen. Sta.	42	9	416	135.0	18	441	229.2		1718					1624			
	42	9	416	124.8	18	441	229.2										

(Continued)

Table 4.3.1. Summary of Stack Input Data and Predicted Concentrations Stack Parameters (Concluded)

Plant Name	Stack Height (meters)	Nominal Load			Maximum Load			Concentrations								
								Nominal Load					Maximum Load			
									24-Hour		3-Hour			24-Hour	3-Hour	
		Exit Velocity (m/sec)	Exhaust Temp. (°K)	Emission Rate (gms/sec)	Exit Velocity (m/sec)	Exhaust Temp. (°K)	Emission Rate (gms/sec)	Max. Annual ($\mu g/m^3$)	Max. ($\mu g/m^3$)	Number Over Standard	Max. ($\mu g/m^3$)	Number Over Standard	Max. Annual ($\mu g/m^3$)	Max. ($\mu g/m^3$)	Number Over Standard	Max. ($\mu g/m^3$)	Number Over Standard
Thilmany Paper Company	58	20	347	10.0	20	347	10.0	21	1957	2	15660	28	64	2200	8	17610	24
	52	14	413	159.2	14	413	179.0										
	53	12	446	1.5	12	446	1.7										
Trane Co.	41	4	566	5.6	4	566	20.3		43					258			
	49	6	577	10.5	6	577	37.1										
	15	26	555	6.8	26	555	40.1										
	24	3	477	0.0	3	477	10.3										
	12	8	533	0.0	8	533	5.5										
	12	25	519	0.0	50	519	9.2										
	8	17	422	0.0	33	422	5.7										
	8	17	422	0.0	33	422	5.7										
Valley Gen. Sta.	122	25	402	608.6	25	402	957.8	5	154	0	1050	0	21	225	0	1547	4
	122	25	402	629.5	25	402	957.8										
Wausau Paper Co.	16	30	439	33.0	30	439	41.2		281					285			
	52	6	505	0.2	6	505	0.2										
	52	10	533	0.3	10	533	0.3										
	17	9	333	74.0	9	333	74.1										
	23	3	333	98.2	3	333	98.2										
	27	2	322	46.4	2	322	46.4										
Weyerhauser Company	21	10	588	49.0	10	589	49.9		92					149			
	43	9	464	22.6	9	464	30.0										
	44	5	466	10.3	5	466	64.4										
	30	10	533	30.5	10	533	45.4										
Weston Gen. Sta.	74	11	440	273.2	13	444	528.1		214					388			
	74	16	433	291.6	16	433	491.3										
Wildwood Gen. Sta. (Manfield)	67	4	450	0.0	7	477	7.2	6	136	0	621	0	24	168	0	602	0
	69	5	422	63.7	10	433	99.1										
	72	8	427	95.3	11	433	142.6										

The predicted concentrations for each plant, for both nominal and maximum load, are given to the nearest microgram per cubic meter. The number of instances that the predicted 24-hour or 3-hour average concentrations exceed the corresponding air quality standard is listed beside the concentration. The model used for each plant is implied from the concentration statistics presented. If entries are made only for the 24-hour average, the VALLEY model was used for that plant, otherwise the CRSTER model was used except the CRSMOD was used for the J.P. Pulliam plant.

Table 4.1.3 presents the results of the model predictions with the plants ranked on the 24-hour average concentration under nominal load conditions. The 17 plants which are ranked the highest in Table 4.1.3 are discussed in detail in the following sections. The highest 17 plants represent those cases when one of the air quality standards has been exceeded by the model predictions. The following remarks will clarify some aspects of the discussion for individual plants which would otherwise be repetitious or need some definition for a better understanding of the discussion. Comparison of the calculated concentration to the air quality standards implies a comparison to the annual standard of 80 $\mu g/m^3$, the 24 hour average of 365 $\mu g/m^3$ and 1300 $\mu g/m^3$ for the 3-hour standard. The values of these standards are not repeated throughout the following sections. The calculated annual average exceeds the standard at two plants, the Badger Paper Company, and Nekoosa-Edwards Paper Company at Port Edwards.

Reference to a receptor location in the text does not imply an air quality monitor was operated at that location. In the discussion of the modeling results, reference to a receptor location means a point for which the concentration has been calculated.

Selection of the model used for each plant is based on the comparison of the minimum plume height, from any stack at the plant, to the amount of relief in the terrain surrounding the plant. If the preliminary analysis of a plant indicates the surrounding terrain is sufficiently rugged to increase the ground-level SO_2 concentrations by at least 20 percent over what would be expected with flat terrain, the CRSTER model is selected, otherwise, the CRSMOD is used, except if the elevations at the receptor locations are sufficiently high that the plume height is lower than the receptor location the VALLEY model is then used.

The VALLEY model output differs from the output of the CRSMOD or CRSTER models in several ways. One important difference is the VALLEY model calculates the concentration which can be compared to the 24-hour standard only, whereas the CRSTER or CRSMOD output provides an annual mean, a 24-hour average for each receptor location and a list of the 50 highest 24-hour averages and 50 highest 3-hour averages. Obviously, it is more desirable to use the CRSTER or CRSMOD model if the terrain restraints are not imposed. There are other reasons to favor the CRS- model also. The VALLEY model computes a concentration based on a single set of meteorological conditions, i.e., wind speed is 2.5 m sec^{-1}, stability class E (slightly stable) and a mixing depth of 1000 meters. The

use of these conditions is based on the assumption that these conditions can exist with the wind blowing from a single sector for a six-hour period. Concentrations calculated based on these conditions will approximate the concentrations expected during unfavorable dispersion conditions and thereby provide a conservative estimate of SO_2 concentrations. Unless on-site observations of actual meteorological parameters are available, meteorological data from other stations should not be used because of the special "valley" situation implied by the use of the model. Wind speed and direction observations in a valley location would be subject to the influences of the channeling of wind along the valley. The CRSTER and CRSMOD models accept the hourly observations of wind speed and direction and the hourly values (interpolated between data points) of the mixing depth. The atmospheric stability category is determined for each hour also. Using the CRSTER or CRSMOD models can provide a much more detailed and realistic data base for making the concentration calculation. The main reservation with the meteorological data for the CRSTER or CRSMOD models is how representative it is for the plant being modeled.

For this study the observations from the closest National Weather Service Station was used for input to CRSTER and CRSMOD models. The surface observations were available from stations in Duluth, Eau Claire, Green Bay, La Crosse, Madison, and Milwaukee. Upper air data, used for determining mixing depth, was available from stations at Green Bay, International Falls at St. Cloud. Identification of which weather station data was used with each plant is presented in Appendix B.

Interpretation of the model output must also emphasize that concentrations are due to emissions from a single plant. SO_2 contributions to a receptor location from another plant are not included in this analysis; nor has a background value for SO_2 been added to the values shown in this report.

The selection of which model to use followed a well defined routine. There are some instances where the use of more than one model would have been desireable. A plant which is located in relatively level terrain and would normally be modeled using the CRSTER model may have been modeled using the VALLEY model because a prominent hill may be located in the vicinity of the plant. A case in point is the Weston power plant. Rib Mountain lies northwest of the plant and that is the only prominent terrain feature in the vicinity. The CRSTER output would indicate very high concentrations for a receptor location on Rib Mountain and the list of the 50 high values would be dominated by calculations for that location, consequently the distribution of high concentrations may not be representative of the true situation. The VALLEY model is used in order to accommodate the terrain features of the area but the limitations of the statistics from the VALLEY model have already been mentioned.

Both the CRSTER and the VALLEY model will calculate higher concentration values for receptor locations which have the highest elevations. Recognizing this fact is also important in analyzing the model output from a couple of standpoints. If the high elevations are typical of the general geographical setting, the higher concentrations calculated will more adequately describe the expected SO_2 concentrations. If the high

elevations occurs at only one or two locations around the plant then the high concentrations noted for that location may not have as much influence on the severity of the SO_2 problem caused by a particular plant. Additional consideration should be given if a high elevation is located in a residential or urban area where high concentrations would be of more consequence than in uninhabited areas.

4.3.1 ALMA Generating Station, Dairyland Power Cooperative

ALMA plant, owned by the Dairyland Power Cooperative, is a coal fired electric generating station located on the east bank of the Mississippi River. The terrain to the east of the plant rises abruptly to elevations of more than 200 meters above the plant site elevation. The plume rise from the plant is not sufficient to rise above these elevations and consequently the plume would impact on the terrain when the wind is from the west. Accordingly, the VALLEY model was selected to evaluate the concentration of SO_2 expected from the plant emissions. The maximum 24-hour average concentration calculated is 6332 $\mu g/m^3$ under nominal load operations and occurs about 1.7 km from the plant. Calculations are not normally made by the VALLEY model to approximate the three-hour concentrations.

The highest concentrations calculated for emissions from the ALMA plant all occur at the receptor locations with high elevations to the east of the plant. There are 23 locations where the calculated 24-hour average concentrations would exceed the 24-hour standard under the meteorological conditions assumed for calculations by the VALLEY model. The actual number of occasions when the SO_2 concentrations exceed the standard is governed by the number of occassions when those met conditions occur.

Data for exhaust gas temperature, velocity and volume are taken from the DNR emission inventory. Fuel use data are taken from the FPC Form 67 for 1973. The sulfur content of the coal used was not available from the FPC form, consequently the average sulfur content was assumed to be 3.1 percent which corresponds to the 1971 average sulfur content of coal

used and is between the maximum and average sulfur content reported in the emission inventory.

4.3.2 American Can Company

The American Can Company plant is located in the city of Green Bay at the confluence of the Fox River and East River. The terrain close to the plant, within 2 kilometers, has less than 8 meters difference between the plant site elevation and the receptor elevations. There are some small hills to the southeast of the plant which rise up as much as 29 meters above the plant site elevation. The low stacks and relatively low plume rise from at least one of the process stacks prescribed the use of the CRSTER model for this plant.

The SO_2 emissions from American Can Company are released from four stacks; three of which serve processes and are between 26 and 35 meters tall. One stack, which is 68 meters tall, serves four boilers which burn No. 5 oil with an average 1.8 percent sulfur content. The fuel is burned on approximately 120 days if the four boilers are not operated on the same days. The fuel is used on an irregular schedule. One boiler is noted to use fuel oil for 59 days while a second one uses fuel oil for 54 days. For modeling purposes it was assumed that these two boilers operate for four months and the SO_2 emission rate is determined by dividing the annual fuel use over 120 days. Approximately five percent of the total SO_2 emissions are due to fuel combustion. Emissions from the four digester tanks account for 87 percent of the total SO_2 emissions and the acid towers contributes the balance of the total. The temperature of the emissions from the acid

tower is comparatively low (305 K) so the only plume rise is due to momentum, consequently the plume height is low.

The maximum 24-hour average for nominal load is 554 $\mu g/m^3$. There are 29 different days when the 24-hour standard may be exceeded. The maximum three-hour concentration predicted is 2817 $\mu g/m^3$. The model calculations indicate the three-hour standard may be exceeded on more than 50 occasions. All of the predicted exceedances of the 24-hour and three-hour standards occur within 1.24 kilometers of the plant which is within the urban area of Green Bay.

4.3.3 Badger Paper Mills, Incorporated

The Badger Paper Mills, Incorporated plant at Peshtigo is located in terrain which is quite flat, especially to the east of the plant. There is only a few meter rise in elevation in the terrain to the west. The stacks at the Badger Paper Company are relatively short stacks, consequently, the CRSTER model was used for this plant. The tallest stack serves the wood burning boilers which have very low SO_2 emission rates. The total emission rate for all the stacks operating at one time is 101.2 $g\text{-}sec^{-1}$; however emissions from stacks 11 and 12 are due to combustion of No. 6 fuel oil which is only burned 17 days of the year, and only eight days for boilers served by stack 10. The concentrations shown are calculated for the condition when all stacks are emitting SO_2 at one time. If these three stacks are not emitting during any period of concern the emission rate would be reduced by approximately 25 percent. The concentrations which are calculated when stacks 10, 11, and 12 are not emitting SO_2 would be reduced slightly under nominal load operating conditions but

more significantly under maximum load conditions. In order to examine this potential effect, the CRSTER model was run twice for this plant, the first run assuming all stacks were emitting continuously and the second run assuming stacks 10, 11, and 12 were not emitting SO_2. The computed concentrations for the two runs are shown in Table 4.3.2.

Table 4.3.2. Concentrations Due to Badger Paper Company Operating With and Without Emissions from Stacks 10, 11, and 12

	Nominal Load			Maximum Load		
	Annual Avg. $\mu g/m^3$	24-Hour Avg. $\mu g/m^3$	3-Hour Avg. $\mu g/m^3$	Annual Avg. $\mu g/m^3$	24-Hour Avg. $\mu g/m^3$	3-Hour Avg. $\mu g/m^3$
With	98	1744	6490	185	1744	6490
Without	83	1738	6490	122	1738	6490

It is obvious from Table 4.3.2 that the most significant impact on predicted air quality, due to inclusion of emissions from stacks 10, 11, and 12, is on the long term standards. If the boilers are operating at maximum capacity, the annual standard would likely be exceeded whether the three stacks in question are operating or not. Under nominal load conditions the annual standard may be exceeded but the 24-hour and three-hour standard would very likely be exceeded, according to the modeling output.

4.3.4 Bay Front Generating Plant, Lake Superior District Power Company

The Bay Front Generating Station is located on the northern edge of Ashland along the shore of Chequamegon Bay. The terrain in the vicinity of the plant is relatively flat with the most noticeable amount of relief occurring in the southwesterly direction from the plant. The highest elevation within 3 kilometers of the plant is 61 meters above the plant

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site elevation. There is enough relief in the terrain to cause an increase of 20 percent or more in the calculated concentrations over what would be expected in flat terrain, consequently the CRSTER model was selected to model this plant.

SO_2 emissions from the Bay Front plant are due to combustion of 3.1 percent sulfur coal and 0.5 percent sulfur distillate oil. There five stacks at this plant which range from 43 to 59 meters in height. There is some seasonal variation to the fuel use rate at the plant with the highest rate of use occurring during January and February and the least amount of fuel use during September through December.

The maximum 24-hour average concentration calculated for nominal load conditions is 401 $\mu g/m^3$ and occurs at a distance of 1.4 kilometers from the plant which is along the outer edge of the developed part of the city. For nominal load conditions, the calculations indicate the 24-hour standard is exceeded twice, but the three-hour standard may be exceeded 11 times. Under maximum load conditions the maximum 24-hour concentration calculated is 464 $\mu g/m^3$ which occurs 2.7 kilometers south of the plant.

The calculated 24-hour average concentrations exceed the standard three times under maximum load conditions, and the three-hour standard may be exceeded 15 times.

4.3.5 Charmin Paper Company

Charmin Paper Company operates two mills in Green Bay, referred to as the East River Plant and Fox River Plant. As the name implies the plants are located along the rivers with those names in the city of Green Bay. The terrain in Green Bay is quite flat and within 3 kilometers of

these two plants there is less than 3 meters relief between the plant site elevation and the receptor locations. There are some hills about 4 to 4.5 kilometers to the southeast of the Charmin plants which rise up to about 45 meters above the plant site elevations. The CRSTER model was selected to evaluate the SO_2 concentrations for both these plants because of the hills to the southeast.

The SO_2 emissions at the Fox River plant are due to coal and No. 2 oil combustion and to process releases. Sulfite liquor burning accounts for 95 percent of the SO_2 emissions. The emissions from the coal, oil, and liquor burning are released from one tall stack (91.7 m) while the remaining emissions are released from four other stacks approximately 20 meters tall.

At the East River plant the only significant contributions to SO_2 emissions comes from combustion of 2.5 percent sulfur coal. The total SO_2 emission rate at the East River plant is approximately 32 g-sec^{1} compared to approximately 502 g-sec^{1} released from the Fox River plant. SO_2 emissions from the East River plant are released from two 43 meter stacks.

The calculated concentrations of SO_2 due to the East River plant emissions stay well below the 24-hour and three-hour standards, with the maximum 24-hour averag being 90 $\mu g/m^3$ and the maximum three-hour concentration is 612 $\mu g/m^3$, under nominal load conditions. The 24-hour standard is not exceeded under maximum load conditions, while the three-hour standard is predicted to be exceeded three times.

The calculated concentrations due to emissions from the Fox River plant do exceed the 24-hour and three-hour standards by a considerable amount on a number of days (22 days for the 24-hour case and over 50 for the three-hour) during the year. The maximum 24-hour average concentration calculated is 691 $\mu g/m^3$. The maximum three-hour concentration calculated for nominal load is 5530 $\mu g/m^3$. Both of these maximums are calculated for a receptor location in the hills to the southeast about 4.5 km distant. Most of the locations where exceedances are indicated are within 1 km of the plant which is within the limits of the city of Green Bay.

4.3.6 Consolidated Papers, Incorporated

One plant of the Consolidated Papers Company is located in Biron Village on the bank of the Wisconsin River. Biron is about 6 kilometers northeast of Wisconsin Rapids. The terrain around Biron is not particularly hilly, some locations within 3.5 kilometers to the north are 15 meters above the plant site elevation. Most of the terrain around this plant is at the same elevation as the plant. Since there is enough relief in the terrain to increase the calculated concentration by at least 20 percent the CRSTER model was used.

The sulfur dioxide emissions are due to combustion of 3.8 percent sulfur coal. No process emissions are listed. Fuel consumption is noted for 250 days per year or five days per week 50 weeks per year.

The calculated concentrations due to emissions do not exceed the 24-hour average standard. The three-hour standard may be exceeded on 13 occasions.

4.3.7 Edgewater Generating Station of Wisconsin Paper and Light Company

The Edgewater generating station is located on the shore of Lake Michigan a few kilometers south of Sheboygan. The highest receptor elevations within 4 kilometers of the plant are approximately 27 meters above the plant elevation. The receptor elevation is high enough that the concentrations may be increased by 20 percent or more due to changes of the terrain, consequently, the CRSTER model was used for this plant. Three stacks emit SO_2 from the combustion in the coal fired boilers. The average sulfur content of the coal is 2.5 percent. The three stacks are 29, 41, and 74 meters tall. The shortest stack emits about seven percent of the SO_2, the 41 meter stack emits about 18 percent and the tall stack releases about 75 percent of the SO_2. The emission rate varies somewhat through the year depending on the fuel use. Significantly lower amount of coal was burned in May and December of 1973 than in the other 10 months.

The highest 24-hour concentration calculated for nominal load conditions was 384 $\mu g/m^3$, slightly higher than the 24-hour standard. The 24-hour standard is exceeded only twice in the calculations for nomimal load conditions but may be exceeded six times under maximum load. The highest 24-hour under maximum load is 590 $\mu g/m^3$. The calculations do not indicate any exceedances of the three-hour standard under nominal load. With maximum load the three-hour standard may be exceeded on nine occasions. The highest predicted three-hour concentration is 2095 $\mu g/m^3$.

4.3.8 Flambeau Paper Company

Flambeau Paper Company located in Park Falls is situated in relatively level terrain where the largest range in relief (about 25 meters) is between the plant site and a receptor location 1.8 kilometers away to the east of the plant. The low stack height and little if any plume rise prescribed the use of the CRSTER model.

Approximately 84 percent of the SO_2 emissions from Flambeau Paper result from the three digester blowpit stacks which are all rather short stacks and operate at temperatures which are relatively low compared with gases emitted from boilers. Emissions from boiler operation are primarily due to combustion of coal and No. 6 oil. Additional emissions are caused by burning pulp liquor but this occurs on only about 60 days per year. If pulp liquor were to be burned continuously for a whole day the total emission rate for the plant would be increased by about 25 percent. In all there are eight stacks included in the Flambeau Paper Company modeling. Stacks 10, 11, and 12 serve boilers while stacks 13-16 serve processes. Estimates were made for the flow rate of gases from stacks 14, 15, and 16 using data from reference[1]. Since emissions from the six stage evaporator are vented through windows, only the emission rate, Q, represents actual data, stack parameters for a "dummy" stack are estimated to meet the requirements of the model.

Under the conditions described to the model the Flambeau Paper Company would cause concentrations of SO_2 to exceed the 24-hour average

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[1] "Exhaust Gases from Combustion and Industrial Processes," Engineering Science, Inc., Washington, D.C., 1971.

on 29 occasions during a year. The three-hour standard may be exceeded on as many as 50 occasions.

4.3.9 Marquette Cement Company

Marquette Cement Manufacturing Company in Milwaukee emits sulfur oxides to the atmosphere from one stack which serves the limestone and shale clinker process. The emission rate is 88.88 grams per second (705.4 lb/hr) which results in the predicted 24-hour maximum concentration to be 452 $\mu g/m^3$ (the only value exceeding the standard), and a three-hour maximum of 902 $\mu g/m^3$. All of the high concentrations occur to the northwest of the cement plant where ground elevations rise to approximately 35 m above the elevation at plant site. The plume height is well above the rise of the terrain, however, so the high concentrations are not due to the plume impacting on the receptor site. All of the high concentrations occur within 1 km of the plant.

The emission rate is based on the emission factor provided in the DNR emission inventory and the maximum throughput data provided. The predicted concentrations for nominal load and maximum load are not greatly different from each other. There was no information provided to indicate any variation in the production rate.

4.3.10 Mosinee Paper Corporation

Mosinee Paper Corporation plant located in Mosinee, along the Wisconsin River. The terrain to the west of the plant is relatively flat but to the east and southeast there are ridges that rise up somewhat more than 30 meters, within 2 kilometers, from the plant site elevation. SO_2 is

emitted from seven stacks which range from 27 to 38 meters high. Most of the SO_2 is due to coal combustion and these emissions are released from the 27 meter stacks. The average sulfur content of coal burned was 2.1 percent in 1973. There are no SO_2 emissions attributed to process operations listed in the emission inventory. The maximum 24-hour concentration calculated for nominal load is 959 $\mu g/m^3$ which occurs within 1 kilometer of the plant. The CRSTER model output indicates the 24-hour standard for SO_2 concentrations may be exceeded on more than 50 days during a year, in the locality of the plant. The maximum three-hour concentration predicted is 4363 $\mu g/m^3$, under nominal load conditions. Concentrations predicted for maximum load conditions are much higher than nominal load, but if all boilers do not operate near capacity at any one time, the maximum load predictions do not reflect a realistic situation.

4.3.11 Nek-Ed Paper Company, Port Edwards Mill

One mill of the Nekoosa-Edwards Paper Company is located in Port Edwards, on the Wisconsin River. The paper mill located to the southeast of the town. It is also about 4 kilometers northeast of Nekoosa and the city of Wisconsin Rapids is about 6 kilomenters north of the Port Edwards mill. The terrain is generally uncomplicated. There are some rolling hills in all directions, but the maximum relief which occurs within 5 kilometers of the plant is about 23 meters to the east of the plant. The SO_2 emissions are due to combustion of No. 6 fuel oil which has an average sulfur content of one percent and to process emissions. The emissions from

the digester blow relief account for about 72 percent of the SO_2 released, the "absorp" tower accounts for 24 percent, and the balance of SO_2 is from combustion of fuel oil. Sulfur dioxide is emitted from three stacks. The process stacks are 30 meters high and the stack serving the boilers is 65 meters high.

The maximum 24-hour average concentration calculated is 1203 $\mu g/m^3$. There are at least 50 different days when emissions from this plant may cause the concentrations of SO_2 to exceed the 24-hour standard. The maximum predicted three-hour concentration is 5333 $\mu g/m^3$. The model computations indicate there are at least 50 different occasions when the three-hour standard may be exceeded. These are nominal load results.

4.3.12 J. P. Pulliam Generating Station, Wisconsin Public Service Corporation

The J. P. Pulliam Generating Station is located in the city of Green Bay on the shore of Green Bay at the mouth of the Fox River. The terrain throughout most of the city of Green Bay is quite level, but a few hills are located on the southeast side of the city. The plumes from the J. P. Pulliam are high enough that a significant increase in ground-level concentrations would not be expected due to the rise in elevations along the hills mentioned; the CRSMOD model was selected to model this plant.

The SO_2 emissions from the Pulliam plant are primarily due to combustion of coal with an average sulfur content of 2.8 percent.

There are seven stacks at the Pulliam plant from which the SO_2 is emitted. Four of the stacks are 55 meters tall while three with the highest emission rate are 72 meters tall.

The predicted maximum 24-hour average concentration is 487 $\mu g/m^3$ due to emissions from the Pulliam plant under nominal load conditions. The predicted concentrations indicate the 24-hour standard may be exceeded on five different occasions during the year (with an additional eight within 10 percent of the standard), under nominal load conditions and on nearly 38 occasions under maximum load. The highest 24-hour average concentration predicted for maximum load conditions is 653 $\mu g/m^3$. The maximum three-hour average concentration predicted for nominal load is 1098 $\mu g/m^3$ and is 2602 $\mu g/m^3$ for maximum load conditions.

4.3.13 Rock River Generating Station of the Wisconsin Power and Light Company

The Rock River plant is situated on the west bank of the Rock River, in a rural area approximately 6 kilometers north of urban Beloit. The terrain rises abruptly to 15 meters above the plant elevation, 1 kilometer east of the palnt. More gradually rising terrain (elevations 15 to 30 meters above plant elevations) lies further to the east. Significant bluffs (elevations 55 to 60 meters above plant elevations) are encountered about 6 or 7 kilometers to the east-southeast and east-northeast of the plant, and 4 to 6 kilometers to the west-southwest of the plant. Preliminary modeling analysis indicated that the terrain surrounding the plant is sufficiently rugged to increase ground level SO_2 concentrations by at least 20 percent over what would be expected in flat terrain.

Sulfur dioxide emissions result from combustion of 2.8 percent sulfur coal. The SO_2 is emitted from two 76 meter stacks in approximately equal amounts. There is some seasonal variation in the emissions with the

greater amounts of fuel burned in the first four months and lesser amounts of fuel used in the last four months of the year.

The maximum 24-hour average concentration calculated for nominal load is 311 $\mu g/m^3$, and for maximum load conditions, the maximum is 268 $\mu g/m^3$. The maximum three-hour concentration is 1298 $\mu g/m^3$ in the nominal load condition, and 1208 $\mu g/m^3$ for the maximum load. The single plant emissions do not cause the SO_2 concentrations to exceed air quality standards.

4.3.14 Scott Paper Company

The Scott Paper Company is located in the town of Oconto Falls on the Oconto River. The developed portion of the town is generally within 1 kilometer of the paper mill. The terrain within 2 kilometers of the plant is generally level with a range in elevation at plant site to the higher receptor locations being only 28 meters. Due to some instances when the plume height is very low, the plume may impact on the terrain, consequently, the VALLEY model was used to calculate concentrations for this plant.

There are seven stacks which emit SO_2 from this plant. The most significant source of SO_2 in terms of emission rate is noted in the emission inventory as process 75, the pulp liquor burning process. The concentrations predicted by the model assume that this process is operating, however, pulp liquor burning is noted to occur on only 60 days per year. The principle source of SO_2 emissions on a continuous basis are the pulp digester units. The low volumetric flow rate given for these processes result in a low exit velocity for the stacks serving those processes and the overall result is a very small plume rise from four short (15 meter) stacks.

The highest concentration predicted is 401 $\mu g/m^3$ for nominal load, and 449 $\mu g/m^3$ for maximum load. The slight difference between the nominal and maximum load is due to a slight difference in the volumetric flow rate between the two conditions. There is no significant difference between the two calculations.

4.3.15 Stoneman Generating Station

The Stoneman Plant in Cassville is located on the east bank of the Mississippi River. The terrain near the plant rises to over 250 meters within 2 kilometers of the plant in the north and northeasterly directions from an elevation of 190 meters at the plant site. The effective plume height from at least one stack is calculated to be less than the height of the terrain, consequently, the VALLEY model is selected for calculating concentrations.

All of the SO_2 emissions from the Stoneman Plant are due to oil and coal combustion. Oil burned had an average of 0.6 percent sulfur while the coal used averaged 3.6 percent sulfur.

The calculated concentrations of SO_2 exceed the 24-hour standard for both the nominal load and the maximum load. The model output indicates the 24-hour standard may be exceeded at 20 different locations around the plant under nominal load conditions.

4.3.16 Thilmany Pulp and Paper Company

Thilmany Pulp and Paper Company is located in the town of Kaukauna on the Fox River. The terrain in the vicinity of the plant rises from 185 meters elevation at the plant site to 226 meters elevation along some

ridges within 4.5 kilometers to the southwest of the plant and to elevations of 272 meters at some locations which are 14 kilometers southeast of the plant. In general, the plant is situated about 30 meters below most of the surrounding terrain. The most developed portion of Kaukauna lies within 1 kilometer in the westerly directions of the Thilmany plant.

The SO_2 emissions are due to combustion of pulp liquor that has an average sulfur content of 3.4 percent, bituminous coal with an average of 3.2 percent sulfur, and No. 6 fuel oil with an average sulfur content of 2.0 percent.

The SO_2 is emitted from three stacks which range from 52 to 58 meters tall. The highest emission rate is due to the combustion of coal. There are no SO_2 emissions from process sources listed in the emission inventory.

The calculated maximum concentrations are very high for one particular day when the wind was blowing from the plant towards the receptor location with the highest elevation, and the mixing depth was quite low. The maximum 24-hour average concentration calculated for nominal load on the day described is 1957 $\mu g/m^3$. The second highest 24-hour average concentration calculated is 404 $\mu g/m^3$. Those are the only two occasions when the 24-hour average is exceeded for nominal load conditions. The maximum 24-hour concentration calculated for maximum load conditions is 2200 $\mu g/m^3$, but the second highest concentration is 452 $\mu g/m^3$. The 24-hour standard is exceeded on eight occasions under maximum load conditions. The maximum three-hour average concentration

calculated is 15660 $\mu g/m^3$ for nominal load, however, the second highest three-hour average concentration is 3229 $\mu g/m^3$. Under nominal load conditions, the three-hour standard may be exceeded on 28 different occasions.

4.3.17 Wausau Paper Mills Company

The Wausau Paper Mills Company is located in Brokaw which is situated in a valley along the Wisconsin River. The terrain around the Wausau Paper Mill is unique among all the plants studied, rising abruptly in almost all directions. The relief of the terrain within 3 kilometers of the plant ranges up to 80 meters above the plant elevation. The steepest slopes and highest elevations occur to the east of the plant. The VALLEY model is used to predict concentrations in this geographic situation.

Emissions to the atmosphere occur through at least five stacks. The SO_2 emissions are due primarily to losses from the magnesium bisulfite processes identified in the emission inventory as processes numbered 30 and 31. Another significant source is process 32, the pressure release valves for the digester tank. No recovery of SO_2 from these processes is assumed. There was no fuel data provided for boilers served by stacks 15 and 16. Those two stacks are therefore not included in this modeling work. Boiler 20, served by stack 14, is used only 70 days per year, and emissions from the incinerator served by stack 11 are noted to occur only 90 days per year. The input to the model assumes these two sources are emitting SO_2, therefore, the model predictions would indicate concentrations for days when the maximum rate of emissions is occurring. The VALLEY model-predicted 24-hour average concentration of SO_2 due to emissions from the Wausau Paper Company

plant is 281 $\mu g/m^3$ for nominal load conditions, and 285 $\mu g/m^3$ for maximum load conditions. These concentrations are well below the 24-hour average standards. However, a special note should be added for the Wausau Paper Company with regard to these predicted concentrations, which appear to indicate an acceptable level of SO_2 concentration in the plant vicinity. Conversations with members of the Wisconsin DNR have indicated that significant damage to vegetation has occurred which has been attributed to SO_2 emissions from the Wausau Paper Company; as a result, a special monitoring and analysis study of the SO_2 concentrations is being conducted for DNR by another consultant organization. That more intensive study addressed to that unique site should provide a more definitive explanation of whether an SO_2 problem exists in that area than could be provided under the resources available to this overview study of a large number of plants.

Due to the peculiar geographic setting of this plant, being located on a bend in a steep-sided river valley which thus approximates a nearly complete bowl in shape, the ventilation of the valley is restricted; the long-term average concentrations may well be higher than would normally be expected, even when the 24-hour average concentration is within acceptable limits. This is exactly the condition (long-term moderate-level exposure) which causes some forms of damage to vegetation, and may be the situation here.

4.3.18 Summary of Remainder of Modeled Sources

The lowest ranked 17 plants in Table 4.1.3 all had predicted concentrations which were well below the air quality standards. Even though the annual emissions for some of these plants exceed the emission rate of plants ranked in the upper half of the table, the concentrations remain low for several reasons. The most important reason is the effective height of the plume and the regularity of the emission rate. At five of the plants, Oak Creek, Valley and Menasha power plants, the Oscar Mayer plant and the Charmin Paper Company East River plant, the 3-hour standard may be exceeded under maximum load conditions. To achieve the calculated concentrations though, the boilers would need to be operating at 95 percent of capacity (maximum load condition) during the meteorological conditions which existed for the time those concentrations were calculated.

4.4 SPECIAL CONSIDERATIONS

Some mention has been made throughout Section 4 of plants which present a unique situation which does not lend itself particularly well to the treatment designed for most of the plants. These special situations include plants which generate some SO_2 sources on an irregular schedule, the plants which are located in a true valley location and the plants which are situated along Lake Michigan which are likely to be operating when fumigation conditions occur.

4.4.1 Special Cases

One instance of these special situations has been described in Section 4.3.17. The Wausau Paper Company at Brokaw operates in a bowl-like geographical location where the dispersion of emissions is restricted by the shelter provided by the valley. The SO_2 problem there has been recognized and a special study is being done to further understand the impact of the SO_2 emissions on the surrounding ground-level concentrations. There are several other plants which operate in valley like settings although the terrain does not restrict the dispersion of emissions as much as the Brokaw location does, for instance, the paper mills and power plants located along the Wisconsin and Mississippi Rivers. The Alma power plant is located on the Mississippi River with a high bluff located very close to the east of the plant. This Alma plant is being changed so that emissions will be released from a stack over 200 meters high. The input to modeling for this study used the 1973 configuration with 3 stacks which are 61 meters high or less. The Trane Company and French Island power plant are similarly situated at La Crosse. Since meteorological data is available from La Crosse, a more detailed study of those plants could be made using the VALLEY model.

There are several major sources of SO_2 in Milwaukee which constitute a special situation because they are close together and compound the SO_2 problem due to the overlapping of the plumes, and the addition of SO_2 from the area sources which exist there. Further, the city is located on the edge of Lake Michigan where fumigation and trapping conditions will occur more frequently than at locations farther removed from a large body of water.

4.4.2 Contiguous Sources

There are ten areas (La Crosse, Madison, Beloit, Milwaukee, Green Bay, Wisconsin Rapids, Sheboygan, Cassville, Wausau, and Menasha) in which the emissions from contiguous sources might be expected to interact in such a way as to reinforce pollutant concentrations in some locations. Each of these is discussed briefly in this section.

The interactive effects (or lack of them) is discussed in the validation treatment of Section 4.2 for La Crosse, Madison and Beloit. In effect, they are essentially insignificant in any of these three communities.

The multiple source cases in the Milwaukee and Green Bay areas, coupled with the probability of significant other SO_2 sources, produces situations in which it could well be misleading to conduct a simplified type of contiguous-source analyses in this section: multiple-source regional modeling is required here. This subject is mentioned further in Section 6.2.

Wisconsin Rapids:

The Wisconsin Rapids area contains, from northeasterly to southwesterly, strung along the Wisconsin River in a line some ten miles long, the plants of Consolidated Biron, Consolidated 4th Avenue (Wisconsin Rapids) Nekoosa - Port Edwards, and Nekoosa in Nekossa. Analysis shows that there may well be interactive effects here in the case of 24-hour maxima; of particular concern is the likelihood that the Port Edwards plant may be impacting significantly on, and adding significantly

to, the maxima in Nekoosa. Since the Port Edwards plant clearly is the principal contributor here, additional analysis may not be needed. Interactive effects of the two Consolidated plants with each other, and with the Nekoosa plants, appear unimportant.

Sheboygan:

In the Sheboygan area the Edgewater power plant and the Kohler Company are located about 6 kilometers apart, aligned along a line oriented from northwest to southeast. The Kohler Company is upwind of the Edgewater plant during the times when air is moving west to east. Although Kohler Company was not modeled it appears from preliminary modeling that any contributions from Kohler to the vicinity downwind of Edgewater would be nominal and the additive effects would occur out over Lake Michigan. The concentrations of SO_2 due to emissions from Edgewater in the northwest direction are quite low (maximum annual mean at 4.2 km is 11 $\mu gm.^{-3}$) and the interaction effect is not significant enough to be of concern.

Cassville:

In the vicinity of Cassville the Stoneman and the Nelson/Dewey generating stations are located along the Mississippi River. Previous modeling and analysis of these two plants showed that the interactive effects of the plumes from both plants has little effect on the predicted ground-level concentrations. The cause of any exceedance of the air quality standard can be attributed to single plant emissions.

Wausau:

In the Wausau area there are three plants which are relatively close together; they are the Mosinee Paper Company, the Weston power plant and the Weyerhauser Paper Company at Rothschild. All three plants are located along the Wisconsin River within 15 kilometers of each other. The Weyerhauser Company is about 5 kilometers north of the Weston power plant and Mosinee Paper Company is about 9 kilometers south of the Weston plant. The VALLEY model was used for the Weston plant and the Weyerhauser Paper Company so the annual means are not available to assess the impact of contributions from both plants to a common location. The Mosinee Paper Company causes high SO_2 concentrations within 1.5 kilometers of the plant. Longer distances from the plant would require additional modeling. The Wausau area may be of sufficient interest to warrant additional study.

Menasha:

The Menasha Corporation, John Strange Division, in Menasha is located about 1 kilometer east of the Menasha Electric and Water power plant. The additive effect of the annual means for common locations around these plants would not cause the concentration to exceed the annual standard. Similarly, if the maximum concentrations from each plant were to occur at a common location it is not likely that the 24-hour standard would be exceeded.

The Kimberly Clark Paper Company and the Thilmany Paper Company are located about 6 kilometers apart on a line that runs west to east.

The Kimberly Clark plant was not modeled hence the effect of overlapping plumes cannot be assessed. The maximum 24-hour concentrations due to emissions from the Thilmany Paper Company may be greater than 250 μgm^{-3} in the vicinity of the Kimberly Clark plant hence there is a possibility of significant interaction from both plants. The annual average would not, however, likely exceed the 80 μgm^{-3} standard due to interaction from both plants.

4.5 OVERALL RESULTS

The plants listed in Table 4.1.3 indicate the extent of the SO_2 problem determined by this study. There are 15 different plants which may cause SO_2 concentrations to exceed the air quality standards. All three air quality standards may be exceeded due to emissions from the Badger Paper Company and from Nekoosa-Edwards Paper Company at Port Edwards.

The frequency of occurrence that the standards are exceeded is an important consideration also. The very high concentrations may be due to a peculiar meteorological condition which may not exist in fact but may be due to interpolating between data points, as with the mixing depth for instance. If the high concentration values occur more than once or twice it is more likely that the cause of the high concentration prediction is due to actual conditions rather than erroneously created conditions. This does not imply that the maximum values are not valid, it is just a caveat to the analyst that all the possibilities which can cause a high concentration must be explored to the satisfaction of the analyst. The highest 24-hour concentration of all plants is predicted for the Alma plant. The change in the plant configuration which is underway has been

mentioned previously and will probably significantly reduce the impact of emissions from that plant.

The very high 3-hour average calculated for the Thilmany plant occurs only once; the remaining 3-hour averages drop down to levels more in line with expected values and comparable to other similar plants.

The plants which are modeled with CRSTER or CRSMOD have statistics regarding the number of times a standard may be exceeded and those data are presented in Table 4.3.1. Of the 15 plants* for which exceedances are indicated for nominal conditions, three were modeled with the VALLEY model. The CRS model calculations for the remaining 12 plants show that three of those plants would exceed both the 24-hour and 3-hour standard more than 50 times during the year. Three more of those plants would exceed both standards more than 20 times during the year. The remaining six plants would cause exceedance of the 24-hour standard five times or fewer and the 3-hour standard would be exceeded in a variety of instances ranging from zero to more than 50. The maximum load calculations generally show an increased level and number of exceedances.

The 17 plants which rank the lowest in Table 4.1.3 do not appear to cause a problem with regard to the air quality standards, unless under special circumstances they could cause occasional exceedances e.g., they are contiguous to other SO_2 sources, or the operating schedule causes short-term releases of a high quantity of SO_2 or if all the SO_2 emissions for each plant have not been inventoried and hence not included in the model input.

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* The top 17 in Table 4.1.3 less Rock River, which shows no exceedances, and Wausau, which is uncertain, as discussed in Section 4.3.17.

Section 5.0

FINDINGS

The concentrations calculated for the plants modeled range from well above the air quality standards to very low values. The number of times the standards have been exceeded has been discussed in detail in previous sections. It is apparent that there are likely to be repeated violations of the standards by seven of the plants modeled. Those seven plants are: Pulliam power plant, Badger Paper Company, Flambeau Paper Company, Mosinee Paper Company, Nekoosa-Edwards Paper Company at Port Edwards, Charmin Paper Company (Fox River) and American Can Company. The maximum values of the 24-hour averages computed by the VALLEY model indicate that the standard may very well be exceeded at two additional plants in at least one location near each plant whenever the meteorological conditions exist which are specified as the VALLEY model input. Those two plants are the Stoneman power plant and Scott Paper Company at Oconto Falls. The modeling output indicates there is a good possibility of the standards being exceeded due to emissions from six other plants, but the certainty of those instances is not as high because the frequency of the predicted occurrence is relatively low. The uncertainties of the model output which reflect both the ability of the model to accurately predict ground-level concentrations and the accuracy of the input data must be considered when analyzing the predictions for these plants. The six plants referred to in this category are: Bay Front power plant, Edgewater power plant, Marquette Cement, Wausau Paper Company, Consolidated Paper Company (Biron), and Thilmany Paper Company.

The Alma power plant is ranked with the highest 24-hour concentrations but the changeover in the plant configuration will render these predictions useless except to indicate the conditions which existed in 1973.

Interpreting the results of the output from the VALLEY model is difficult because of the limited amount of data output. There are limitations to the utility of the model but for those situations where the plume is below some terrain elevations, the VALLEY model must be used. The CRSTER model will predict very high concentrations in the cases where it is appropriate to use the VALLEY model. The problem of additive concentrations due to emissions from more than one plant has been addressed but cannot be resolved with any degree of confidence without some additional study. In 10 different localities where 2 or more plants are located relatively close together (within 5-10 kilometers) a brief investigation indicates the overlapping effect would probably not be significant in at least four of those localities. Of the remaining six, at least two (Milwaukee and Green Bay) are recommended for multiple-source regional analysis.

Section 6.0

RECOMMENDATIONS FOR FURTHER STUDY

6.1 SPECIAL CASES

The analysis of the plants modeled has shown there are some plants which have unique operating schedules or the plant is located in a peculiar geographical setting which will require some special treatment to obtain more satisfactory modeling results, if the plants are of special interest. The plants located in terrain with hills or bluffs higher than the exhaust gas plume are the most prominent example. The plants which were examined using the VALLEY could be modeled using more detailed description of the meteorological conditions. This would require a more intensive study of the meteorological parameters which are input to the model for the region in question.

6.2 CONTIGUOUS PLANTS

There are several regions where a number of SO_2 sources are located relatively close to one another and the plumes from more than one plant may affect a given location; these are usually in locations where significant non-specific (area) sources of SO_2 also are present. The models used in this study do not treat the multiple plant/area source problem.

Two cities (Green Bay and Milwaukee) have been particularly noted in Section 4.4 as being areas which would justify regional modeling. In fact, regional modeling is the only realistic approach to use for a modeling study in those areas.

GEOMET

Other important areas which were indentified where significant interaction of the plumes from more than one plant are noted in Section 4.4 and may warrant more sophisticated modeling if the plants are of sufficient interest.

Appendix A

DESCRIPTION OF MODELS USED

CRSMOD Program

The CRSMOD program is designed to calculate the contributions of emissions from a single plant site to ambient air quality levels, defined in the same time scales as the National Ambient Air Quality Standards (NAAQS), when the plant is located on generally flat terrain. The basic program was developed by the Meteorology Laboratory of EPA's National Environmental Research Center at Research Triangle Park, N. C. Hourly, daily (24-hourly) and annual mean concentrations are calculated at a specified set of locations surrounding the plant.

The contributions to ambient air concentrations from the plant are computed using a modified version of the Gaussian plume equation (e.g., Turner 1970). The modifications include the following:

- Trapping of the plume between the top of the mixing layer and the ground surface
- Uniform vertical mixing of the plume in the mixing layer beyond a critical distance
- Exclusion of any ground level effects from plumes released above the mixing layer.

Trapping is simulated using the method of multiple images (e.g., Turner 1970) which results in a convergent infinite series of terms representing reflection from the upper and lower boundaries of the trapping layer. Beyond a certain distance the trapping effects result in a nearly uniform vertical distribution. The computational procedure is simplified by identifying where this point exists and introducing an appropriate simplification at this point. The modified Gaussian plume equation for the concentration from a single stack is

$$x(x,y) = \frac{Q\,R(x)}{\sigma_y(x)\,u}\ \exp\left\{-\frac{1}{2}\left(\frac{y}{\sigma_y(x)}\right)^2\right\} \qquad \text{(A-1)}$$

$R(x) = 0,$ $\qquad H > L$

$R(x) = \frac{1}{2.5066L},$ $\qquad H \le L$ and $\frac{\sigma_z(x)}{L} > 1.6$

$R(x) = \frac{1}{\Pi\sigma_z(x)} \sum_{n=-\infty}^{\infty} \exp\left\{-\frac{1}{2}\left(\frac{H+2nL}{\sigma_z(x)}\right)^2\right\},$ $\qquad H \le L$ and $\frac{\sigma_z(x)}{L} \le 1.6$

where $\chi(x,y)$ = concentration at location x, y (g/m^3)

x = distance downwind from plant (m)

y = distance crosswind from plant (m)

Q = pollutant emission rate (g/sec)

u = wind speed (m/sec)

$\sigma_y(x)$ = horizontal diffusion parameter (m)

$\sigma_z(x)$ = vertical diffusion parameter (m)

H = plume height (stack height plus plume rise) (m)

L = height of the top of the mixing layer (m).

Concentrations computed for each stack of the plant are summed to determine a single concentration from the plant.

Concentrations are calculated assuming that emission and meteorological conditions are fixed for one hour periods. A new set of meteorological parameters are used for each hour of the year. Twenty-four hours are averaged to determine daily mean concentrations; daily means are averaged to determine annual means. A pollutant emission rate is computed for each plant stack for each month. However, the characteristics of the stack which determine plume rise (i.e., height, diameter, temperature and exit velocity) remain fixed. The plume height is determined by Briggs' plume rise equations (Briggs 1971, 1972).

In Briggs' equations momentum, buoyancy and potential temperature are assumed to be conserved. The horizontal component of motion of plume elements is assumed to be equal to a mean wind speed. The plume radius is assumed to increase linearly with the plume rise during the first stage, which is followed by a second stage in which the rate of change of the plume radius is proportial to the one-third power of the plume radius. These assumptions were fitted to empirical data by Briggs to derive equations for leveled off plume height in neutral and unstable atmospheres which show plume rise to be inversely proportional to wind speed and directly proportional to a power law of the initial buoyancy flux of the stack gases. In stable atmospheres Briggs' equations show plume rise is proportional to the one-third power of initial buoyancy flux divided by wind speed times a stability parameter.

A wind speed is estimated for each stack assuming a power law for the vertical profile as follows:

$$u = u_o\left(\frac{h}{7}\right)^{p(S)}$$

where u_o = reported wind speed (m/sec)

$p(S)$ = wind profile parameter (see Table A-1)

h = stack height (m).

The diffusion parameters $\sigma_y(x)$ and $\sigma_z(x)$ are the standard values developed from Pasquill's data by Gifford (e.g., Turner 1970) which are dependent on distance from the plant and the Pasquill stability class.

Table A-1. Wind Speed Profile Parameters

Pasquill Stability Class	Wind Speed Profile Parameter
A	0.1
B	0.15
C	0.2
D	0.25
E	0.3
F	0.3

The Pasquill stability class is determined from standard NOAA hourly weather records using the objective scheme of Turner (1964). The mixing layer heights must be derived from twice daily upper air observations. These are then linearly interpolated with time to obtain hourly estimates. The other required meteorological parameters (i.e., wind direction, wind speed and air temperature) are determined from the standard NOAA hourly weather records.

Concentrations are calculated for a grid work of receptor locations which are defined in terms of from 1 to 36 directions from the plant and for each of five radial distances. For a given wind direction (α) a receptor polar coordinate (r,θ) has the following cartesian coordinates (x,y) for use in equation A-1.

$$x = r$$

$$y = r\ (\alpha - \Pi - \theta)$$

where α and θ are measured in radians.

The annual maximum 24-hour mean concentration under nominal load conditions is determined by identifying the maximum 24-hour mean concentration among all the daily values computed for a year at each of 180 receptor locations. Since the plume rise characteristics which depend on a plant's operating load vary with wind speed and stability conditions, the maximum 24-hour mean concentration may occur on different days for nominal and maximum operating loads. However, rather than recalculate the daily mean concentration at all 180 receptors for the entire year, it has been found that the annual maximum 24-hour mean concentration under maximum load conditions can be determined by examining 24-hour mean concentrations for the 20 days which produce the highest daily means under nominal load conditions. To compensate for the possibility of underestimation as a result of looking at only 20 days, the reported value for maximum load conditions has been increased by 10 percent over the calculated value.

CRSTER Program

The CRSTER program calculates the contributions of emissions from a single plant site to ambient air quality by a method which is exactly the same as that used by CRSMOD with one exception. This exception makes this model applicable to uneven as well as flat terrain. The modification requires that the height of the receptor locations above the plant elevation be input to the program. This program should only be used when these receptor heights are judged to significantly alter the air quality estimates.

The exception which makes this program different is a correction which is made to the plume height for each stack to account for the height of the receptor. In equation (A-1) the parameter H should be replaced by $H-z_r + z_s$, where z_r is the elevation (above sea level in meters) of the receptor point and z_s is the elevation of the plant. The correction must be made for each receptor-stack pair considered.

VALLEY Program

The VALLEY program calculates the contribution of emissions from one or more plant sites to ambient air quality levels, for a 24-hour representative maximum concentration when the plant is located in complex terrain. The model is designed to be used when the elevation of receptor locations of interest is equal to or greater than the elevation of the effective stack height (stack height plus plume rise) for one or more of the plant stacks under stable conditions and five knot winds.

The basic program, developed by EPA's Office of Air Quality Planning and Standards in Durham, N.C., computes contributions to ambient air concentrations from emissions by multiple stacks. Based on a modified Gaussian plume equation, the calculations follow procedures adapted from Turner (1970). In view of the uncertainties which are inherent in modeling the transport and dispersion of stack plumes in complex terrain, several simplifying assumptions have been introduced which reduce the model's sensitivity to diffusion parameters (e.g., the horizontal diffusion parameter σ_y is eliminated). The major assumptions in the model as it has been used in this study are:

- The height of the plume centerline above the ground is decreased by the elevation of the receptor above the base of the stack.
- The pollutant is uniformly distributed in the horizontal over a 22.5 degree sector.
- The plume centerline is never less than 10 meters from the ground.
- Atmospheric conditions are stable.

The second assumption is equivalent to assuming that the wind direction is randomly distributed within a 22.5 degree sector over the period of interest. In making 24-hour concentration estimates, it is assumed that the wind direction will be within any given 22.5 degree sector with stable conditions for six hours out of the 24-hour period, more than once per year. The equation for the contribution to the 24-hour mean concentration at a receptor from emissions by a single stack is:

$$x(x) = \frac{2.03}{\sigma_z(x)\, u\, x} \left(\frac{Q}{4}\right) \exp\left[-\frac{H^2}{2\sigma_z(x)^2}\right]$$

$$\sigma_z(x) = a\, x^{b} + c$$

$$H = \max\left[10,\ h_s + \Delta H + z_s - z_R\right]$$

$$\Delta H = \min\left[27{,}436\ \frac{F}{u}^{0.333333},\ 76.505\ F^{0.25}\right]$$

$$F = 3.12139\ V\ \frac{T_s - 293}{T_s}$$

$$V = \frac{\pi}{4}\, v\, d^2$$

where $x(x)$ = concentration at receptor (g/m^3)

u = wind speed (m/sec)

x = distance from stack to receptor (m)

Q = stack emission rate (g/sec)

$\sigma_z(x)$ = vertical diffusion parameter (m)

a,b,c = empirical constants (see Table A-2)

z_s = elevation of base of stack (m)

z_R = elevation of receptor (m)

h_s = stack height (m)

d = stack diameter (m)

v = stack gas exit velocity (m/sec)

T_s = stack gas exit temperature (°K)

$\min[m,n]$ = minimum of values m and n

$\max[m,n]$ = maximum of values m and n

All the calculations in this study which have used the VALLEY program have been made to estimate representative maximum 24-hour concentrations. As a result the model has been used to simulate light wind, stable situations which are likely to occur. No attempt has been made to estimate annual mean concentrations. All calculations were made assuming a representative light wind, stable situation with a speed of 2.5 m/sec. The empirical constants used to represent the vertical diffusion values represent the commonly used values adopted from Pasquill's curve for moderately stable conditions (class E).

Table A-3. Empirical Constants Used for σ_z Function

Stack to Receptor Distance (m)	a	b	c
< 100	0.06	0.854	0.0
100 to 1,000	0.1345	0.745	-1.1
≥ 1,000	52.6	0.15	-126.0

Contributions from all stacks are summed in estimating a total concentration from all identified stacks. Concentrations are calculated at 112 receptors located at 16 points equally spaced on each of seven circles. The circles have radii which are from one to seven multiples of a specified base circle radius.

References:

Briggs, G. A. 1971. "Some Recent Analyses of Plume Rise Observations." In: Proceedings of the Second International Clean Air Congress. Academic Press, New York, N. Y. pp. 1029-1032.

Briggs, G. A. 1972. "Discussion - Chimney Plumes in Neutral and Stable Surroundings." Atmospheric Environment, Vol. 6, pp. 507-510.

Turner, D. B. 1964. "A Diffusion Model for an Urban Area." Journal of Applied Meteorology, 3, pp. 83-91.

Turner, D. B. 1970. Workbook of Atmospheric Dispersion Estimates. Office of Air Programs Publication No. AP-26, Environmental Protection Agency.

CRSTER OUTPUT

...UNT PLANT (ADCR 240)
MADISON GAS AND ELECTRIC COMPANY

SEC MADISON UPPER AIR GREEN BAY

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&NAM1
KSTL=5 IUR=1 ITAP,IPUN= 0 0
IDATA,IMAX,ILOTS= 0 0 0
NST= 1
NPOL= 1 JTAP= 1 INPUT= 2
NSEA= 1 FCONV= 0.3048006

D-ADJUSTMENT FACTORS

STACK#	NOM-SO2	S1 -SO2	S2 -SO2	S3 -SO2	S4 -SO2	S5 -SO2
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
8	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
11	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
13	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
14	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
16	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
17	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
18	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
19	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

DAY-- 1 1 1

PLANT ELEVATION (FEET ABOVE SEA LEVEL)-- 860.0

RECEPTOR ELEVATIONS (FEET ABOVE SEA LEVEL)

DIRECTION	RING#1	RING#2	RING#3	RING#4	RING#5
1	860.0	850.0	845.0	900.0	920.0
2	860.0	850.0	850.0	870.0	930.0
3	860.0	850.0	860.0	850.0	860.0
4	860.0	850.0	860.0	890.0	922.0
5	860.0	855.0	870.0	860.0	860.0
6	860.0	850.0	880.0	870.0	920.0
7	860.0	845.0	845.0	850.0	912.0
8	845.0	845.0	845.0	860.0	900.0
9	845.0	845.0	845.0	880.0	950.0
10	845.0	845.0	845.0	910.0	910.0
11	845.0	845.0	860.0	910.0	870.0
12	845.0	845.0	855.0	940.0	850.0
13	845.0	845.0	850.0	860.0	845.0
14	845.0	845.0	860.0	850.0	850.0
15	845.0	845.0	845.0	850.0	850.0
16	845.0	845.0	845.0	850.0	890.0
17	845.0	845.0	845.0	860.0	870.0
18	845.0	845.0	870.0	920.0	920.0
19	845.0	845.0	850.0	860.0	850.0
20	845.0	845.0	850.0	870.0	850.0
21	845.0	845.0	870.0	860.0	920.0
22	850.0	845.0	850.0	850.0	890.0
23	855.0	860.0	855.0	860.0	880.0
24	890.0	860.0	860.0	860.0	910.0
25	870.0	860.0	860.0	930.0	1010.0
26	880.0	860.0	870.0	930.0	900.0
27	910.0	845.0	870.0	845.0	900.0
28	870.0	845.0	845.0	860.0	845.0
29	845.0	845.0	845.0	845.0	845.0
30	845.0	845.0	845.0	845.0	845.0
31	845.0	845.0	845.0	845.0	845.0
32	845.0	845.0	845.0	845.0	845.0
33	845.0	845.0	845.0	845.0	845.0
34	845.0	845.0	845.0	845.0	900.0
35	845.0	845.0	845.0	845.0	885.0
36	855.0	845.0	845.0	900.0	880.0

STACK # 1-- BLOUNT PLANT STACK A
STACK # 2-- BLOUNT PLANT STACK B
STACK # 3-- BLOUNT PLANT STACK 2
STACK # 4-- BLOUNT PLANT STACK 3
STACK # 5-- BLOUNT PLANT STACK 4
STACK # 6-- BLOUNT PLANT STACK 5

STACK	STRATEGY TYPE	SO2 EMISSION RATE (GMS/SEC)	PART EMISSION RATE (GMS/SEC)	HEIGHT (METERS)	DIAMETER (METERS)	EXIT VELOCITY (M/SEC)	TEMP (DEG.K)	VOLUMETRIC FLOW (M**3/SEC)
1	NOM	0.02	0.0	27.43	1.68	8.84	533.00	19.60
2	NOM	0.01	0.0	28.04	1.98	7.92	422.00	24.49
3	NOM	48.07	0.0	76.20	4.[illegible]	[illegible]	[illegible]	[illegible]

4	NOM	7.85	0.0	76.20	2.54	5.94	466.00	38.41
5	NOM	106.94	0.0	76.20	2.54	11.95	405.00	60.55
6	NOM	128.69	0.0	76.20	2.54	11.95	405.00	60.55

RANGE(KM)= 1.24 1.95 3.02 4.66 7.21

SEASONAL VARIATIONS BY CASE #

1 2.04 1.94 0.85 0.29 0.12 0.10 0.07 0.30 1.80 1.87 1.46 1.21

BLOUNT PLANT (ADCR 240)

NOM--SO2

MAXIMUM MEAN CONC= 7.0267E-06 DIRECTION= 9 DISTANCE= 7.2 KM

ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR

DIR	RANGE	1.3 KM	1.9 KM	3.0 KM	4.7 KM	7.2 KM
1		9.99536E-08	2.14738E-07	2.83062E-07	3.88220E-07	2.63879E-07
2		6.26573E-07	1.82675E-06	3.26544E-06	4.05759E-06	5.26544E-06
3		4.56133E-07	8.35347E-07	1.10988E-06	8.55037E-07	6.53816E-07
4		1.21863E-06	2.51537E-06	3.70136E-06	4.65860E-06	3.37918E-06
5		6.18092E-07	8.48531E-07	8.69291E-07	6.36720E-07	4.26690E-07
6		9.57739E-07	1.26754E-06	2.53276E-06	2.38583E-06	2.63701E-06
7		3.15888E-07	2.34934E-07	2.59185E-07	2.45306E-07	2.48826E-07
8		1.28210E-07	2.21129E-07	2.46065E-07	2.52211E-07	2.11201E-07
9		7.87118E-07	2.25995E-06	3.80691E-06	5.46888E-06	7.02665E-06
10		3.18066E-07	6.00253E-07	7.39867E-07	9.88863E-07	6.16724E-07
11		5.07896E-07	1.69827E-06	3.42549E-06	4.81413E-06	3.08887E-06
12		2.14928E-07	4.92021E-07	7.96072E-07	1.15111E-06	5.09940E-07
13		9.20193E-07	1.68042E-06	3.12837E-06	3.73737E-06	2.98888E-06
14		2.53805E-07	6.15382E-07	1.02019E-06	8.52065E-07	6.03311E-07
15		8.37849E-07	2.60251E-06	4.35492E-06	4.82963E-06	4.09656E-06
16		1.87784E-07	4.19306E-07	5.65640E-07	5.17088E-07	4.14119E-07
17		3.58607E-09	2.77883E-09	1.33147E-09	5.10422E-10	1.77458E-10
18		1.15932E-09	8.16479E-10	4.05359E-10	3.10185E-10	1.21758E-10
19		4.87185E-08	1.35680E-07	2.23421E-07	2.28159E-07	1.58471E-07
20		4.98603E-07	1.83563E-06	3.51655E-06	4.23004E-06	3.21168E-06
21		1.44124E-07	4.04698E-07	7.70537E-07	7.45998E-07	6.12362E-07
22		3.65717E-07	1.24622E-06	2.57113E-06	2.99004E-06	3.23042E-06
23		1.50860E-07	4.29253E-07	5.78787E-07	5.46559E-07	4.34364E-07
24		7.31993E-07	1.39463E-06	2.42027E-06	2.67433E-06	2.87904E-06
25		7.97519E-08	1.50600E-07	2.01839E-07	2.48858E-07	2.98406E-07
26		8.36562E-08	1.58010E-07	2.69976E-07	4.39011E-07	2.64012E-07
27		1.68891E-06	1.50955E-06	3.61160E-06	3.98327E-06	4.17385E-06
28		2.06971E-07	3.29691E-07	4.65703E-07	4.83911E-07	3.43316E-07
29		1.53893E-07	7.47125E-07	1.62581E-06	2.04539E-06	1.91654E-06
30		5.93787E-08	1.91266E-07	3.35111E-07	3.51728E-07	2.65956E-07
31		1.51527E-07	4.89361E-07	9.61496E-07	1.20120E-06	1.14575E-06
32		6.01495E-08	1.37542E-07	2.10085E-07	2.05901E-07	1.53143E-07
33		1.98910E-07	7.44178E-07	1.49309E-06	1.86570E-06	1.73204E-06
34		4.42043E-08	1.19909E-07	1.87157E-07	1.88420E-07	1.92086E-07
35		1.55634E-07	2.60010E-07	2.81248E-07	2.21644E-07	2.41376E-07
36		4.89728E-07	1.11978E-06	1.75526E-06	3.23768E-06	1.99805E-06

BLOUNT PLANT (ADCR 240)

NOM--SO2

YEARLY MAXIMUM 24-HOUR CONC= 2.0051E-04 DIRECTION= 9 DISTANCE= 4.7 KM DAY= 4

HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 1.3 KM	1.9 KM	3.0 KM	4.7 KM	7.2 KM
1	5.4119E-06 (229)	9.8380E-06 (17)	1.7777E-05 (49)	2.4938E-05 (49)	1.7143E-05 (49)
2	3.8879E-05 (16)	9.8562E-05 (16)	1.4236E-04 (16)	1.4083E-04 (16)	1.2957E-04 (13)
3	3.4726E-05 (40)	5.4933E-05 (15)	4.8237E-05 (15)	3.3258E-05 (15)	2.1806E-05 (15)
4	1.2057E-04 (40)	1.7644E-04 (40)	1.5044E-04 (40)	1.4136E-04 (50)	1.0643E-04 (50)
5	6.1820E-05 (51)	5.8330E-05 (40)	4.6483E-05 (15)	3.3366E-05 (10)	2.3537E-05 (10)
6	8.7422E-05 (24)	8.0150E-05 (268)	9.4388E-05 (24)	7.6160E-05 (341)	7.8696E-05 (1)
7	4.8075E-05 (24)	1.6614E-05 (51)	1.0776E-05 (268)	1.2725E-05 (40)	1.9117E-05 (24)
8	1.5094E-05 (288)	1.9038E-05 (288)	1.4106E-05 (288)	8.9335E-06 (288)	7.1232E-06 (14)
9	4.9880E-05 (288)	1.1433E-04 (4)	1.7946E-04 (4)	2.0051E-04 (4)	1.6293E-04 (4)
10	3.0729E-05 (54)	3.8312E-05 (54)	2.8077E-05 (54)	2.4415E-05 (11)	1.5865E-05 (11)
11	4.1484E-05 (54)	6.2245E-05 (19)	1.0844E-04 (19)	1.2650E-04 (5)	8.2434E-05 (5)
12	3.2154E-05 (89)	2.8297E-05 (23)	4.9835E-05 (23)	6.2343E-05 (23)	3.0807E-05 (23)
13	3.6792E-05 (89)	4.7868E-05 (52)	7.3323E-05 (52)	8.0981E-05 (37)	6.4184E-05 (37)
14	1.3298E-05 (288)	2.0780E-05 (288)	2.8014E-05 (288)	2.6447E-05 (37)	2.0452E-05 (37)
15	5.1705E-05 (288)	1.2208E-04 (28)	1.7754E-04 (28)	1.6612E-04 (28)	1.1866E-04 (28)
16	1.1474E-05 (288)	1.8356E-05 (46)	2.7505E-05 (46)	2.5281E-05 (46)	1.9111E-05 (46)
17	3.8306E-07 (191)	2.0604E-07 (183)	4.8076E-08 (183)	3.5517E-08 (214)	1.4104E-08 (214)
18	2.7969E-07 (139)	1.5981E-07 (139)	7.8425E-08 (139)	4.8017E-08 (115)	1.8989E-08 (115)
19	2.4150E-06 (139)	8.2907E-06 (45)	1.4645E-05 (45)	1.4693E-05 (45)	9.7305E-06 (45)
20	2.0046E-05 (45)	7.4785E-05 (45)	1.2585E-04 (45)	1.3237E-04 (45)	8.8985E-05 (45)
21	3.5686E-06 (141)	1.0674E-05 (302)	2.2031E-05 (349)	2.2142E-05 (349)	1.6625E-05 (349)
22	1.5283E-05 (338)	4.4397E-05 (338)	1.0439E-04 (260)	1.0562E-04 (260)	8.6260E-05 (271)
23	1.8496E-05 (80)	3.2590E-05 (80)	4.3542E-05 (36)	3.4564E-05 (36)	2.7965E-05 (36)
24	6.4844E-05 (56)	7.4913E-05 (56)	1.1189E-04 (56)	1.0372E-04 (56)	8.5731E-05 (56)
25	7.3129E-06 (114)	8.7788E-06 (272)	1.2782E-05 (272)	1.5153E-05 (272)	2.2944E-05 (323)
26	9.0630E-06 (71)	1.4548E-05 (71)	2.2716E-05 (21)	2.7552E-05 (21)	1.5267E-05 (21)
27	9.0850E-05 (55)	8.0254E-05 (55)	1.6248E-04 (55)	1.4498E-04 (21)	1.1893E-04 (21)
28	3.4526E-05 (35)	3.9475E-05 (35)	3.2024E-05 (35)	2.2010E-05 (35)	1.4011E-05 (35)
29	9.3873E-06 (31)	4.7316E-05 (31)	9.1545E-05 (31)	9.8219E-05 (31)	9.9854E-05 (280)
30	3.6570E-06 (146)	9.4727E-06 (32)	1.6548E-05 (32)	1.6041E-05 (31)	1.2371E-05 (31)
31	9.2978E-06 (146)	2.4408E-05 (32)	4.7218E-05 (279)	5.6295E-05 (279)	4.8074E-05 (279)
32	4.7346E-06 (146)	5.0359E-06 (288)	7.8132E-06 (282)	8.3855E-06 (282)	6.9427E-06 (280)
33	1.8371E-05 (284)	5.5903E-05 (284)	8.4440E-05 (282)	1.0581E-04 (282)	9.2442E-05 (282)
34	3.4221E-06 (264)	8.2597E-06 (264)	1.1258E-05 (72)	1.1482E-05 (3)	1.0274E-05 (3)
35	2.0460E-05 (333)	2.2297E-05 (333)	1.4363E-05 (333)	7.5358E-06 (326)	9.4807E-06 (18)
36	4.0019E-05 (333)	4.2429E-05 (333)	7.5115E-05 (285)	1.0706E-04 (285)	7.2702E-05 (285)

MAXIMUM DAILY CONCENTRATIONS

DAY	24-HOUR CONCENTRATION	DIRECTION	DISTANCE
4	2.0051E-04	9	4.66
28	1.7754E-04	15	3.02
60	1.7644E-04	6	1.45
55	1.6248E-04	27	3.02
21	1.5514E-04	27	3.02
18	1.4238E-04	2	3.02
50	1.4138E-04	6	4.66
15	1.3850E-04	6	3.02
65	1.3237E-04	20	4.66
13	1.3003E-04	2	4.66
17	1.2980E-04	2	4.66
1	1.2661E-04	9	4.66
5	1.2650E-04	11	4.66
14	1.2228E-04	11	4.66
11	1.1519E-04	9	7.21
47	1.1565E-04	15	4.66
304	1.1516E-04	9	7.21
285	1.1507E-04	6	4.66
49	1.1506E-04	2	4.66
24	1.1248E-04	6	1.45
56	1.1146E-04	24	3.02
282	1.0581E-04	33	4.66
260	1.0562E-04	22	4.66
33	1.0490E-04	15	3.02
363	1.0463E-04	9	4.66
12	1.0185E-04	2	4.66
10	1.0058E-04	6	4.66
315	1.0056E-04	36	4.66
280	9.9856E-05	24	7.21
31	9.8219E-05	24	4.66
23	9.7585E-05	11	4.66
46	9.7470E-05	15	3.02
3	9.7443E-05	27	4.66
300	9.5060E-05	11	4.66
302	9.4872E-05	15	4.66
289	9.4764E-05	11	4.66
57	9.4511E-05	22	4.66
27	9.4452E-05	20	4.66
339	9.3035E-05	11	4.66
347	9.2126E-05	20	4.66
349	9.1960E-05	20	4.66
328	9.0964E-05	27	7.21
305	8.8348E-05	9	7.21
51	8.7644E-05	11	4.66
358	8.6926E-05	27	3.02
244	8.6821E-05	36	4.66
271	8.6260E-05	22	7.21
268	8.4713E-05	6	3.02
38	8.4041E-05	15	4.66
37	8.0961E-05	13	4.66

MAXIMUM COMPUTED 3-HOUR CONCENTRATIONS

CONC	DIST	DIR	DAY	HOUR
8.978E-04	1.95	4	24	15
8.770E-04	1.95	4	15	12
8.386E-04	3.02	4	24	15
8.038E-04	1.95	4	60	12
7.464E-04	3.02	4	24	12
7.460E-04	3.02	4	15	12
6.990E-04	1.26	4	24	12
6.476E-04	1.26	4	51	12
6.396E-04	3.02	4	60	12
6.067E-04	1.95	4	60	15
5.967E-04	1.95	15	288	12
5.825E-04	4.66	4	24	15
5.764E-04	1.95	5	288	15
5.567E-04	1.95	4	288	15
5.515E-04	1.26	4	60	12
5.373E-04	3.02	15	288	12
5.366E-04	3.02	4	60	15
5.360E-04	4.66	5	24	12
5.273E-04	4.66	24	274	21
5.118E-04	4.66	4	15	12
5.046E-04	1.26	27	35	15
5.011E-04	4.66	38	247	21
4.987E-04	1.26	4	15	12
4.945E-04	1.26	5	51	12
4.805E-04	3.02	24	274	21
4.883E-04	1.26	6	288	15
4.759E-04	7.21	2	248	3
4.635E-04	7.21	9	289	21
4.626E-04	3.02	4	288	15
4.610E-04	4.66	4	262	12
4.537E-04	7.21	3	286	18
4.506E-04	4.66	31	274	21
4.472E-04	7.21	9	303	12
4.472E-04	4.66	33	282	0
4.457E-04	1.26	4	24	15
4.455E-04	3.02	4	333	9
4.378E-04	1.95	6	51	12
4.367E-04	1.95	27	35	15
4.360E-04	3.02	6	288	15
4.303E-04	4.66	4	60	12
4.282E-04	1.95	4	333	9
4.258E-04	7.21	24	274	21
4.204E-04	1.95	5	60	12
4.207E-04	7.21	9	241	0
4.188E-04	1.95	5	15	12
4.187E-04	4.66	22	260	12
4.177E-04	1.95	3	15	12
4.175E-04	1.95	11	54	15
4.131E-04	1.26	4	60	15
4.126E-04	7.21	2	316	9

VALLEY OUTPUT

GEOMET

STONEMAN PLANT FILE NO. 220002 AQCR 068 JAN 17

PRESS= 1000.0 IUR= 2
TEMP= 293.0 ICONT= 1
DMIX= 1000.0 ISHORT= 2
DMNI= 100.0 ISWIT= 1
HLIFE= 0.0 ISOR= 2
GRID= 38.21 IPUN= 0
ALWT=1000000.0
STARER= 16.00
WSA= 2.50 0.0 0.0 0.0 0.0 0.0

SCALE USED ON THE FOLLOWING MAPS:

0 KM 0.382KM 0.764KM 1.146KM 1.528KM 1.911KM 2.293KM
....+.... ....+.... ....+.... ....+.... ....+.... ....+.... ....+....

STABILITY CLASS--1

	SPEED IN METERS/SEC: 2.50	0.0	0.0	0.0	0.0	0.0
N	0.0	0.0	0.0	0.0	0.0	0.0
NNE	0.0	0.0	0.0	0.0	0.0	0.0
NE	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.0	0.0	0.0	0.0
WSW	0.0	0.0	0.0	0.0	0.0	0.0
W	0.0	0.0	0.0	0.0	0.0	0.0
WNW	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	0.0	0.0	0.0	0.0	0.0
NNW	0.0	0.0	0.0	0.0	0.0	0.0

STABILITY CLASS--2

	SPEED IN METERS/SEC: 2.50	0.0	0.0	0.0	0.0	0.0
N	0.0	0.0	0.0	0.0	0.0	0.0
NNE	0.0	0.0	0.0	0.0	0.0	0.0
NE	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.0	0.0	0.0	0.0
WSW	0.0	0.0	0.0	0.0	0.0	0.0
W	0.0	0.0	0.0	0.0	0.0	0.0
WNW	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	0.0	0.0	0.0	0.0	0.0
NNW	0.0	0.0	0.0	0.0	0.0	0.0

STABILITY CLASS--3

	SPEED IN METERS/SEC: 2.50	0.0	0.0	0.0	0.0	0.0
N	0.0	0.0	0.0	0.0	0.0	0.0
NNE	0.0	0.0	0.0	0.0	0.0	0.0
NE	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.0	0.0	0.0	0.0
WSW	0.0	0.0	0.0	0.0	0.0	0.0
W	0.0	0.0	0.0	0.0	0.0	0.0
WNW	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	0.0	0.0	0.0	0.0	0.0
NNW	0.0	0.0	0.0	0.0	0.0	0.0

STABILITY CLASS--4

	SPEED IN METERS/SEC: 2.50	0.0	0.0	0.0	0.0	0.0
N	0.0	0.0	0.0	0.0	0.0	0.0
NNE	0.0	0.0	0.0	0.0	0.0	0.0
NE	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.0	0.0	0.0	0.0
WSW	0.0	0.0	0.0	0.0	0.0	0.0
W	0.0	0.0	0.0	0.0	0.0	0.0
WNW	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	0.0	0.0	0.0	0.0	0.0
NNW	0.0	0.0	0.0	0.0	0.0	0.0

STABILITY CLASS--5

	SPEED IN METERS/SEC: 2.50	0.0	0.0	0.0	0.0	0.0
N	1.0000	0.0	0.0	0.0	0.0	0.0
NNE	1.0000	0.0	0.0	0.0	0.0	0.0
NE	1.0000	0.0	0.0	0.0	0.0	0.0
ENE	1.0000	0.0	0.0	0.0	0.0	0.0
E	1.0000	0.0	0.0	0.0	0.0	0.0
ESE	1.0000	0.0	0.0	0.0	0.0	0.0
SE	1.0000	0.0	0.0	0.0	0.0	0.0
SSE	1.0000	0.0	0.0	0.0	0.0	0.0
S	1.0000	0.0	0.0	0.0	0.0	0.0
SSW	1.0000	0.0	0.0	0.0	0.0	0.0
SW	1.0000	0.0	0.0	0.0	0.0	0.0
WSW	1.0000	0.0	0.0	0.0	0.0	0.0
W	1.0000	0.0	0.0	0.0	0.0	0.0
WNW	1.0000	0.0	0.0	0.0	0.0	0.0
NW	1.0000	0.0	0.0	0.0	0.0	0.0
NNW	1.0000	0.0	0.0	0.0	0.0	0.0

STABILITY CLASS--6

	SPEED IN METERS/SEC: 2.50	0.0	0.0	0.0	0.0	0.0
N	0.0	0.0	0.0	0.0	0.0	0.0
NNE	0.0	0.0	0.0	0.0	0.0	0.0
NE	0.0	0.0	0.0	0.0	0.0	0.0
ENE	0.0	0.0	0.0	0.0	0.0	0.0
E	0.0	0.0	0.0	0.0	0.0	0.0
ESE	0.0	0.0	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0	0.0	0.0
SSE	0.0	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0
SSW	0.0	0.0	0.0	0.0	0.0	0.0
SW	0.0	0.0	0.0	0.0	0.0	0.0
WSW	0.0	0.0	0.0	0.0	0.0	0.0
W	0.0	0.0	0.0	0.0	0.0	0.0
WNW	0.0	0.0	0.0	0.0	0.0	0.0
NW	0.0	0.0	0.0	0.0	0.0	0.0
NNW	0.0	0.0	0.0	0.0	0.0	0.0

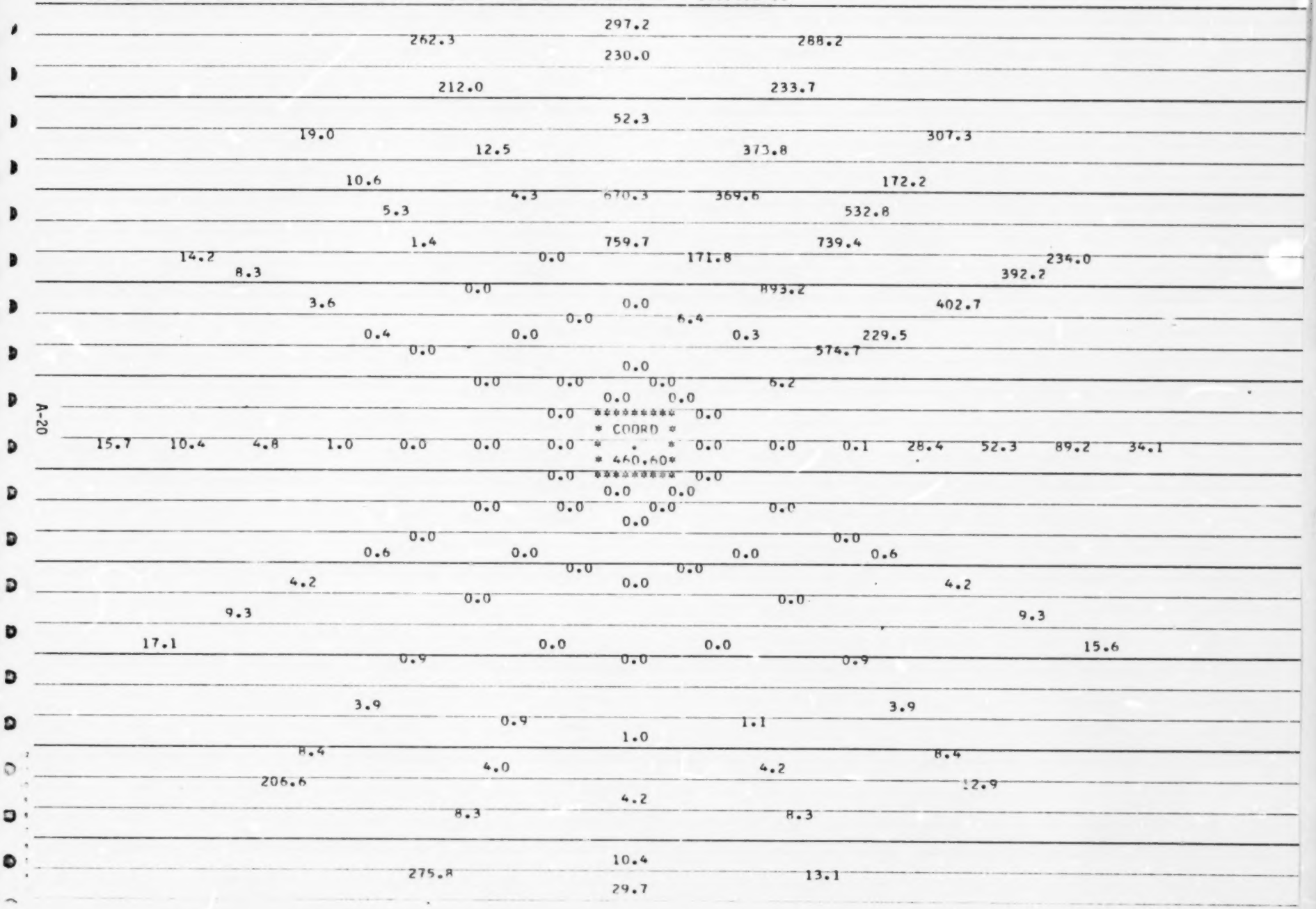
SOURCE DATA:

#	EMISSION RATE	STK HT	TEMP	EXIT VELOCITY	DIAMETER	VOL.FLOW	X-COOR	Y-COOR	SOURCE HT	BRIGUN	BRIGST
1	135.020	42.06	416.00	9.39	1.65	20.08	460.00	60.00	615.00	191.	73.
2	124.810	42.06	416.00	9.39	1.65	20.08	460.00	60.00	615.00	191.	73.

HEIGHT OF RECEPTORS /OR ABOVE PLANT (FEET)

	RING DISTANCES						
DIRECTION	1	2	3	4	5	6	7
N	610.	700.	850.	870.	700.	800.	890.
NNE	610.	770.	790.	820.	840.	800.	860.
NE	610.	710.	860.	890.	890.	770.	870.
ENE	610.	750.	840.	790.	840.	880.	830.
E	610.	605.	630.	700.	700.	720.	650.
ESE	610.	602.	605.	605.	605.	605.	605.
SE	610.	602.	600.	600.	600.	600.	600.
SSE	610.	605.	605.	605.	600.	600.	600.
S	600.	600.	605.	605.	600.	605.	640.
SSW	600.	605.	605.	600.	600.	600.	850.
SW	600.	605.	600.	600.	600.	600.	800.
WSW	600.	605.	605.	605.	605.	605.	610.
W	600.	605.	605.	605.	605.	605.	605.
WNW	600.	600.	600.	600.	600.	600.	600.
NW	605.	600.	610.	610.	610.	610.	620.
NNW	610.	620.	620.	640.	640.	790.	840.

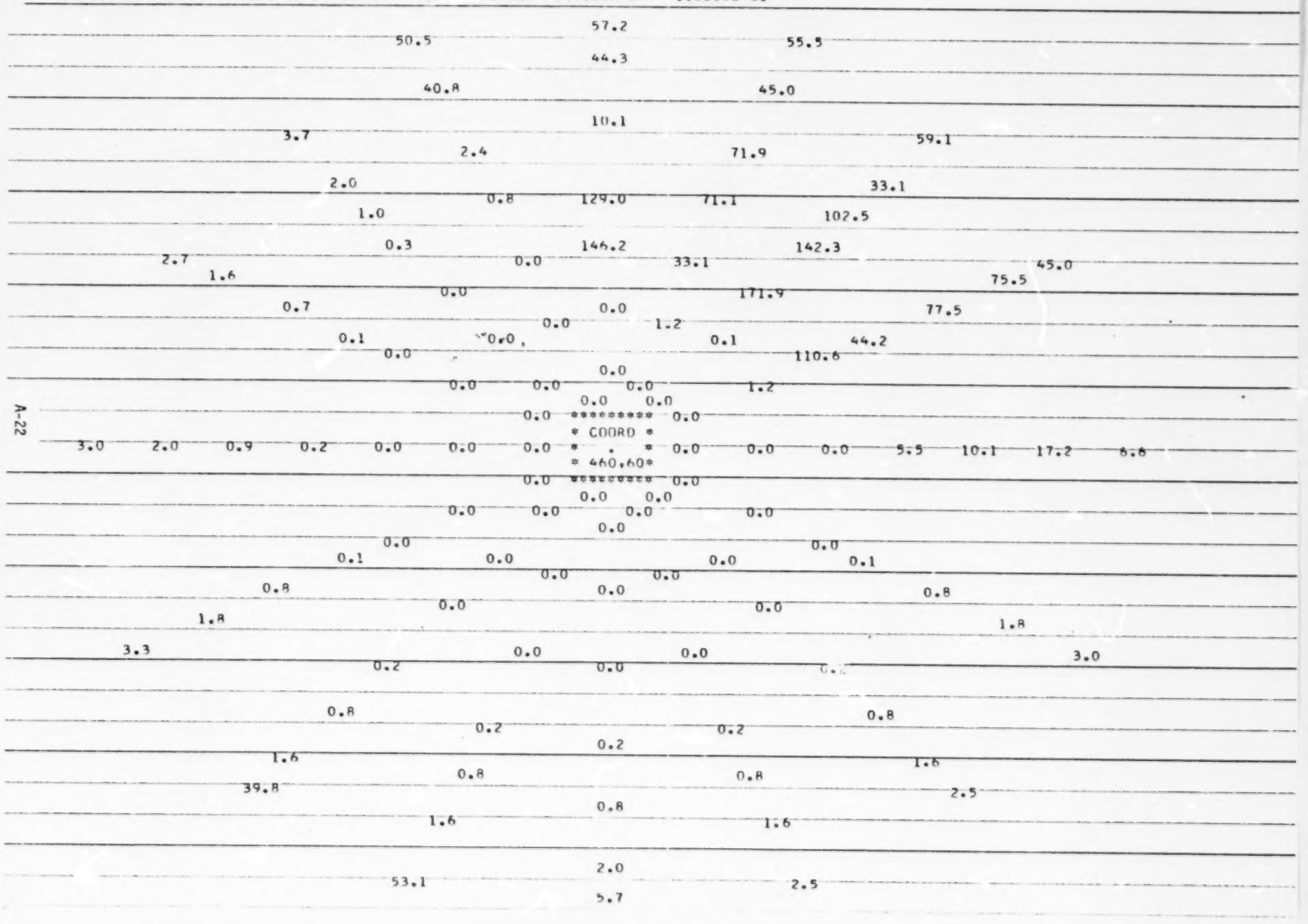
STACK# 1 PLANT: STONEMAN PLANT FILE NO. 220002 AQCR 068 JAN 17
TO CORRECT TO STP MULTIPLY BY 0.996 CONC HAS BEEN DIVIDED BY 1.0000E+00



STACK# 2 PLANT: STONEMAN PLANT FILE NO. 220002 AOCR 068 JAN 17
TO CORRECT TO STP MULTIPLY BY 0.996 CONC HAS BEEN DIVIDED BY 1.0000E+00

274.7
242.5 266.4
212.6
195.9 216.0
48.4
17.6 284.1
11.5 345.5
9.8 159.1
3.9 619.6 341.6
4.9 492.5
1.3 702.2 683.5
13.2 0.0 158.8 216.3
7.7 362.5
0.0 825.7
3.3 0.0 372.2
0.0 5.9
0.4 0.0 0.3 212.2
0.0 531.2
0.0
0.0 0.0 0.0 5.8
0.0 0.0
0.0 ********* 0.0
* COORD *
14.5 9.6 4.5 0.9 0.0 0.0 0.0 * . * 0.0 0.0 0.1 26.3 48.4 82.4 31.6
* 460.60*
0.0 ********* 0.0
0.0 0.0
0.0 0.0 0.0 0.0
0.0 0.0
0.5 0.0 0.0 0.5
0.0 0.0
3.9 0.0 3.9
0.0 0.0
8.6 8.6
15.8 0.0 0.0 14.4
0.8 0.0 0.8
3.6 3.6
0.8 1.0
0.9
7.8 7.8
3.7 3.9
191.0 11.9
3.9
7.7 7.7
9.6
254.9 12.1
27.4

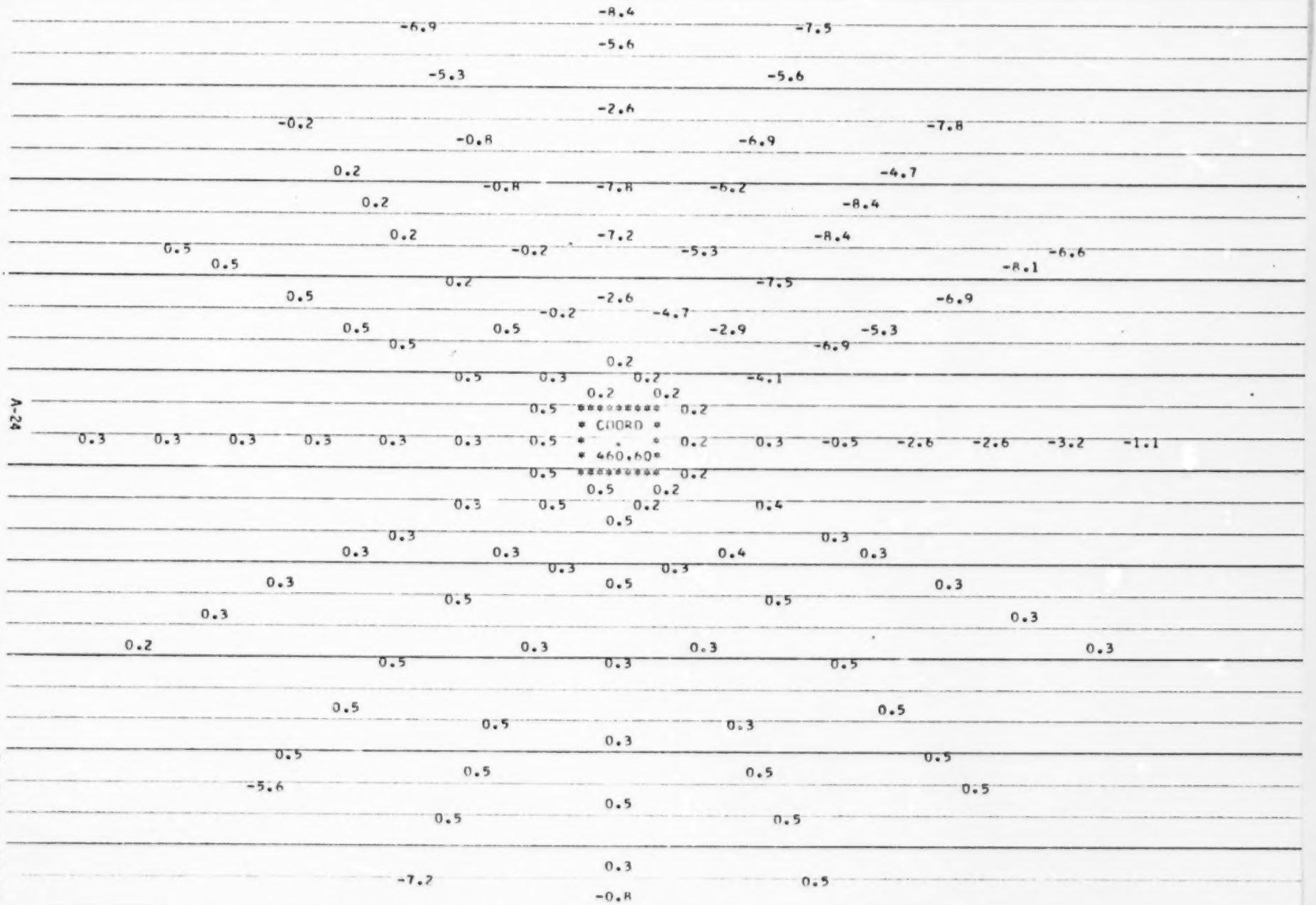
OTAL CONCENTRATIONS--PLANT: STONEMAN PLANT FILE NO. 220002 AQCR 068 JAN 17
TO CORRECT TO STP MULTIPLY BY 0.996 CONC HAS BEEN DIVIDED BY 1.0000E+01



MAXIMUM CONCENTRATION (UGMS/M**3) FOR-- STONEMAN PLANT FILE NO. 220002 AOCR 06B JAN 17

STACK	CONCENTRATION	DIRECTION
1	893.19	45.0
2	825.65	45.0
TOTAL	1718.84	45.0

PLANT: STONEMAN PLANT FILE NO. 220002 AOCR 068 JAN 17
ELEVATION OF THE PLANT ABOVE THE RECEPTOR POINTS IN METERS * 10.0



Appendix B. Meteorological Stations Whose Data Were Used for Modeling Each Plant

Plant Name - Location	Surface Data Station	Upper Air Data Station
Alma Generating Station - Alma	Eau Claire	St. Cloud
American Can Company - Green Bay	Green Bay	Green Bay
Badger Paper Company - Pesthigo	Green Bay	Green Bay
Bay Front Generating Station - Ashland	Duluth	St. Cloud
Black Hawk Generating Station - Beloit	Madison	Green Bay
Blount Street Generating Station - Madison	Madison	Green Bay
Charmin Paper - East River	Green Bay	Green Bay
Charmin Paper - Fox River	Green Bay	Green Bay
Consolidated Paper Company - Biron	La Crosse	Green Bay
Consolidated Paper Company - Wisconsin Rapids	La Crosse	Green Bay
Edgewater Generating Station - Sheboygan	Milwaukee	Green Bay
Flambeau Paper - Park Falls	Eau Claire	St. Cloud
Marquette Cement - Milwaukee	Milwaukee	Green Bay
Menasha Corporation - Menasha	Green Bay	Green Bay
Menasha Electric and Water - Menasha	Green Bay	Green Bay
Mosinee Paper Company - Mosinee	Eau Claire	Green Bay
Nekoosa-Edwards Paper Company - Nekoosa	La Crosse	Green Bay
Nekoosa-Edwards Paper Company - Port Edwards	La Crosse	Green Bay
Niagara Paper Company - Niagara	Green Bay	Green Bay
Oak Creek Generating Station - Oak Creek	Milwaukee	Green Bay
Oscar Meyer - Madison	Madison	Green Bay
Owens-Illinois - Tomahawk	Eau Claire	Green Bay
Pulliam Generating Station - Green Bay	Green Bay	Green Bay
Rock River Generating Station - Beloit	Madison	Green Bay
St. Regis Paper Company - Rhinelander	Green Bay	Green Bay
Scott Paper Company - Oconto Falls	Green Bay	Green Bay
Stoneman Generating Station - Cassville	Madison	Green Bay
Thilmany Paper Company - Kaukauna	Green Bay	Green Bay
Trane Company - La Crosse	La Crosse	St. Cloud
Valley Generating Station - Milwaukee	Milwaukee	Green Bay
Wausau Paper Company - Brokaw	Eau Claire	Green Bay
Weston Generating Station - Rothchild	Green Bay	Green Bay
Weyerhauser Paper - Rothchild	Green Bay	Green Bay
Wildwood Generating Station - Marshfield	Eau Claire	Green Bay